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## NEW TINGITIDAE (HEMIPTERA)

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Received February 11, 1942

The present paper contains the description of three new genera, thirty-six new species, and one new variety of Tingitidae from various countries. The two new combinations proposed are the transfer of *Furcilliger bicolor* Hacker to the genus *Cysteochila* Stal, and *Leptopharsa patria* Drake & Hambleton to the genus *Gargaphia* Stal. In the latter the transverse laminae interrupting the rostral sulcus are very low and easily overlooked. The types of the new species are in the writer's collection.

### *Teleonemia bahiana*, sp. nov.

Elongate, rather narrow, dark brown, the hood testaceous. Head black, with five rather short, brown spines, the median stout and porrect, the hind pair short and mostly concealed by pronotum, the front pair short, suberect. Rostrum extends to meso-metasternal suture, the sulcus broad and cordate on metasternum. Antennae shortly pilose, long, dark brown; segment I moderately stout, one and one-half times the length of II; III long, slightly bent, approximately three times as long as IV. Legs long, slender, dark brown.

Pronotum distinctly convex, pitted, sharply tricarinate, the areolae tiny; lateral carinae slightly concave within in front, indistinctly converging posteriorly; paranota narrow, reflexed, uniseriate; hood moderately overlapping behind when at rest, the outer margin widely concave opposite apex of discoidal area, the areolae (save in costal area) clouded with brown; subcostal area wider, biseriate; discoidal area long, extending beyond middle of elytra, bounded by a costate nervure, narrowed at base and apex, widest a little in front of middle, there six areolae deep; costal area narrow, uniseriate, the areolae very narrow and elongate, a little wider in widest part.

Length, 6.30 mm.; width, 1.35 mm.

Type (female) and 1 paratype, Bahia, Brazil. This species is longer than *T. morio* Stal and has a differently formed hood. In *morio* the rostrum extends considerably beyond the apex of rostral sulcus, and the hood is larger and subglobose.

### *Teleonemia chacoana*, sp. nov.

Very similar to *T. paraguayana* in form and color, but much smaller, the costal area biseriate, the carinae and paranota much less foliaceous. Head brown, with five long, slender, testaceous spines, all directed forward and downward. Antennae rather short, moderately stout, clothed with short, bristly hairs; segment I short, stout, stouter and a little longer

than II; III three times as long as IV. Rostrum reaching on metasternum, the sulcus wider and cordate on metasternum. Eyes moderately large, black. Nervures rather densely clothed with very fine, moderately long, golden hairs.

Pronotum brown, coarsely pitted, convex, finely hairy; triangular projection testaceous, areolate. Carinae strongly foliaceous, with large areolae; median carina distinctly arched in front of middle; lateral carinae not quite as foliaceous, distinctly constricted at base of triangular projection. Paranota large, strongly reflexed, suberect, triseriate in widest part, the areolae moderately large. Elytra wide, widest near apex and at the median transverse fascia, the outer margin widely concave between fascia; costal area wide, biseriate to median fascia, thence mostly triseriate, the areolae (except in fascia) hyaline. Other characters similar to *simulans* Drake.

Length, 4.00 mm.; width, 2.10 mm.

Type (female), Chaco, Paraguay. This species is smaller than *simulans* and the median carina much less foliaceous and arched.

***Teleonemia paraguayana*, sp. nov.**

Moderately long, very broad, testaceous-brown, the elytra with two transverse bands. Rostral sulcus wide, the rostrum reaching nearly to the middle of metasternum. Antennae longer than in *T. simulans* Drake, also the hood larger, the carinae more foliaceous and the costal area much wider and quadriseriate. Hairs on nervures short, sparse, and inconspicuous. Other structures and color very similar to *simulans* Drake.

Length, 4.50 mm.; width, 3.10 mm.

Type (female) Horqueta, Paraguay, Jan. 1938. The very wide, quadriseriate costal area separates this species at once from *T. chilensis* Reed, *chilensis elata* Drake, and *simulans* Drake. The carinae and paranota are strongly foliaceous and the median carina arched in a similar manner as in *simulans*.

***Perissonemia occasa*, sp. nov.**

Similar to *P. borneensis* Distant, but with longer and stouter antennae and with the basal half of costal area biseriate. Antennae shortly pilose, rather stout; segment I slightly stouter and three times as long as II; III a little more than twice as long as IV, the latter blackish. Head with small median tubercles, the hind pair of spines slender, rather short, appressed. Rostrum nearly reaching base of mesosternum, testaceous, blackish at tips; laminae areolate, not very widely separated, concave within on meso- and metasternum, open behind. Pronotum strongly narrowed anteriorly; paranota very narrow, carina-like, wider opposite calli, there with few small areolae; lateral carinae more raised than in *borneensis*, concave within on disc; median carina straight, a little more elevated; collar distinctly raised; calli impressed, black. Costal area with outer margin broadly concave beyond the middle, there somewhat testaceous, uniseriate and areolae larger; biseriate in front.

Length, 4.0 mm.; width, 1.20 mm.

Type (male), Japan, March, 1914, collected by Matsumura. The eyes are smaller and the first antennal segment distinctly shorter than in *borneensis*.

*Perissonemia malacca*, sp. nov.

Brown, the hood, paranota, carinae, costal area and apical portion of elytra testaceous-brown. Antennae very long, slender, brown, the distal segment dark; segment I much stouter and twice as long as II; III very long, very slender, nearly three times as long as IV, the latter slightly enlarged. Rostral channel deep, open behind, testaceous; rostrum extending to apex of sulcus.

Pronotum convex, pitted, sharply tricarinate, the lateral carinae long and converging posteriorly. Hood smaller than in *assamensis* (Dist.) and larger than in *electa* (D. & P.), the paranota narrower than the former. Costal area broader, uniseriate and with larger areolae in the basal half, thence biseriate in widest part. Color and other characters similar to *electa*.

Length, 3.65 mm.; width, 1.20 mm.

Type (female) and paratype Malacca, Perak, Federated Malay States. The very wide costal area and long antennae are distinguishing characters.

*Parada popla*, sp. nov.

Separated at once from *P. taeniophora* Horvath by the biseriate basal portion of costal area of elytra. Head, brown to black, with five short, testaceous spines. Rostrum extending on metasternum. Body beneath dark brown to mostly black. Antennae indistinctly hairy, testaceous, the last segment almost entirely black; segment III approximately three times as long as IV. Legs brownish.

Pronotum moderately convex, tricarinate, black, the hind process brownish; hood brownish, moderately large, narrowed at crest; paranota moderately broad, almost completely reflexed, mostly triseriate brownish testaceous; carinae formed as in *taeniophora*. Elytra brownish testaceous; costal area moderately broad, broader along basal portion, there biseriate, the inner row of areolae much smaller; subcostal area broad, largely triseriate; discoidal area large, broadest beyond middle, narrowed and slightly elevated at apex, the outer boundary a little beyond the middle with a small inflated spot, there marked with black on nervure; sutural area considerably infusate.

Length, 3.10 mm.; width, 1.10 mm.

Type (male) and allotype (female), National Park, Queensland, Australia, Dec., 1935, H. Hacker. Paratypes, numerous specimens, taken with type, Mt. Glorious, Brookfield, Maleny, Tooloom, and Cedar Creek, Queensland. This is the species identified by Hacker as *Cysteochoila* (*Parada*) *taeniophora* Horvath, *Mem. Queen. Mus.*, Vol 1, pt. 1, 1927, p. 24. In the latter species, the costal area is uniseriate with elongate-oval

areolae. The subgenus *Parada* Horvath seems to create a very distinct group and is here raised to generic status.

*Parada popla nigrantis*, var. nov.

Differs from the typical *P. popla* in having the hood, paranota, carinae and pronotum, except triangular process entirely black. The sides of the pronotum are also largely black. Other characters and size similar to *popla*.

Mt. Glorious, Queensland, Australia, May 24, 1930, H. Hacker.

*Parada torta*, sp. nov.

Differs from *P. taeniophora* Horvath by its smaller hood and much broader costal area which has rather large, transverse, triangular areolae. Head ferruginous brown, with five short, testaceous spines. Antennae longer and more slender than *taeniophora*, testaceous, the apical segment (except basal portion) black; segment I short, a little longer and slightly thicker than II; III long, slightly bent, slightly more than three times as long as IV. Rostral channel deep, moderately wide, open behind, the laminae testaceous, areolate, subparallel; rostrum brownish, dark apically, practically reaching end of sulcus. Orifice prominent. Hypocostal ridge narrow, minutely areolate.

Pronotum moderately convex, deeply pitted, tricarinate, the disc brownish black; lateral carinae converging posteriorly, strongly foliaceous, triseriate, completely reflexed and resting on the disc of the dorsal surface of pronotum, there the dorsal margins not touching the median carinae, posteriorly sharply elevated, indistinctly areolate and strongly converging on the triangular process; median carinae sharply raised, not very distinctly areolate; hood small, only about one-half as large as in *taeniophora* Horvath; paranota testaceous, moderately wide, triseriate, strongly reflexed, nearly touching dorsal surface of pronotum, less reflexed at humeral angles. Elytra a little shorter than in *taeniophora* and slightly wider at apex; costal area less reflexed, moderately wide, uniseriate, the areolae moderately large, clear, and mostly rectangular or quadrate. Color and other characters very similar to *taeniophora* Horvath.

Length, 3.00 mm.; width 1.102 mm.

Type (male), allotype (female), and 3 paratypes, Mt. Gipps, Queensland, Australia, April 20, 1930, taken by H. Hacker.

*Cystechila franzeni*, sp. nov.

Similar to *C. tricolor* (Hacker), but with narrow costal area, longer spines on head, and much less pronounced color marking. Head brown, with five long, slender, nearly erect, testaceous spines. Antennae moderately long, slender; segment I brown, short, stout, nearly twice as long as II, the latter brown, obconical; III long, slender, testaceous, two and one-half times as long as IV, the latter mostly black, slightly thickened. Rostral sulcus deep, narrow on mesosternum, very broad and cordate on



metasternum, the rostrum reaching to the base of mesosternum. Eyes moderately large, reddish brown.

Pronotum testaceous, partly embrowned, strongly convex, pitted, tricarinate; carinae foliaceous, each uniseriate, the latter nearly parallel; hood small, pointed at crest; paranota large, formed as in *tricolor*, covering part of lateral carinae, the humeral angles prominent. Elytra testaceous, veinlets considerably embrowned, with an indistinct transverse fascia near middle; costal area largely biseriate; the inner row of areolae tending to be much smaller; discoidal area long, widest near middle, there 4 or 5 areolae deep, narrowed at base and apex, the portion of the boundary in transverse band separating it from subcostal area distinctly raised and blackish; subcostal area narrow, biseriate.

Length, 2.45 mm.; width, 1.10 mm.

Type (male), allotype (female), and 2 paratypes, Ingham, Australia, June 6, 1931, taken by L. Franzen, after whom the insect is named. *C. tricolor* (Hacker) is a strikingly colored species, with conspicuous median fascia, and with wider and entirely biseriate costal area.

*Cysteochila chiniana*, sp. nov.

Smaller than *C. suensoni* sp. nov. and separated from it by its smaller size, longer rostrum, and the paranota raised and not resting upon pronotum over humeri. Head black, with five, testaceous spines, the hind pair appressed. Antennae brown, shortly pilose; segment III approximately three times as long as IV, the latter largely dark fuscous. Legs brown, the tibiae lighter, the tips of tibiae black. Rostral channel deep, rather narrow, the laminae pale testaceous, and meeting behind; rostrum extending to end of sulcus. Legs brown, moderately long.

Paranota moderately convex, tricarinate, the hind portion reticulate; all carinae concealed on disc by overlapping paranota, the lateral carinae concave within and more widely separated posteriorly; paranota considerably inflated above humeri, elsewhere resting on pronotum, the outer margins resting upon and touching over median carina. Elytra moderately wide, not much constricted beyond the middle, the apical portion infusate, with a narrow, transverse band near middle of costal area; costal area biseriate, the areolae moderately large; subcostal area biseriate; discoidal area large, reaching beyond middle of elytra, widest near middle, there seven areolae deep, some of the veinlets partly infusate.

Length, 3.10 mm.; width, 1.20 mm.

Type (male) and 1 paratype, Tien Sun Shan, China, June 20, 1937, taken by E. Suenson. *Suensoni* is a much broader species and with wider costal area; the rostrum reaches to the meso- and metasternal suture.

*Cysteochila suensoni*, sp. nov.

Moderately large, broad, castaneous, with dark fuscous markings. Head with five stout, appressed or nearly appressed yellowish spines. Rostrum brownish, dark apically, extending to meso- metasternal suture;

laminae very thick, whitish, moderately raised, entirely open behind, the sides within on both mesa- and metasternum concave. Eyes large, blackish. Antennae brown, indistinctly pilose, moderately long; segment I very stout, short, a little longer and stouter than II; III slightly narrowed distally, three times as long as IV, the latter slightly thickened and largely dark fuscous.

Pronotum strongly convex, slightly produced in the middle in front, coarsely pitted, tricarinate; triangular process large, the lateral carinae divaricating posteriorly, whitish behind; paranota large, resting closely on the dorsal surface of pronotum, the outer margins barely touching median carina and concealing the lateral carinae, the hind margins more sharply rounded; hood low, rather broad. Elytra broad, with a strikingly marked, transverse band near middle of costal area, which becomes wider on subcostal area and then includes a large part of discoidal area dark fuscous; most of sutural area and apex of costal area dark brown; costal area mostly biseriate, sometimes with the inner row of smaller areolae wanting apically, the outer row of areolae considerably larger, the areolae hyaline except in colored areas; subcostal area biseriate, the areolae smaller; discoidal area large, broad, extending considerably beyond middle of elytra, outer margin sinuate, widest near middle, there seven or eight areolae deep. Legs rather short, brown, the apices of tarsi black. Wings smoky brown, longer than abdomen.

Length, 3.75 mm.; width, 1.52 mm.

Type (female) and 1 paratype, Tien Sun Shan, China, June 20, 1939, collected by E. Suenson, in whose honor the insect is named. This species is distinctly broader than other members of the genus of similar length from China and Japan. The wider costal area and large marginal row of areolae are also distinguishing characters.

*Cysteochila undosa*, sp. nov.

Large, broad, castaneous, with brownish markings. Head black, with five yellowish spines; hind pair of spines rather short, slender, pale, appressed, the others stout and slightly turned downwards. Eyes large, black. Antennae brown, rather stout; segment I short, stout, stouter and longer than II; III long, straight, three times as long as IV, the latter black. Legs brown, the tips of tarsi dark. Body broad, black beneath, clothed with very short, fine, pale hairs. Rostral channel wide, open behind, pale testaceous; rostrum testaceous, dark brown at apex, nearly reaching the base of mesonotum.

Pronotum convex, tricarinate, the lateral carinae divaricating posteriorly and concealed on disc by the overlapping paranota; hood broad, only slightly raised, not produced in front, finely areolate; paranota large, resting closely on the pronotum, covering the lateral carinae on disc of pronotum but not touching the median carina, a small area on each side raised and compressed so as to form a small high point; triangular process entirely reticulate, the areolae similar in size and shape to those of paranota. Elytra very strongly widened opposite apex of triangular pro-

cess of pronotum, the outer margin strongly undulate; costal area extremely wide at broad transverse band, biseriate in front and along the strongly concave outer margin behind, five or six areolae deep in transverse band, there the areolae clouded and smaller; subcostal area narrow, biseriate; discoidal area very large, grayish brown, extending considerably beyond the middle of elytra, narrowed at base and apex, widest near middle, there eight or nine areolae deep, the outer margin curved; sutural area dark brown to fuscous, the areolae becoming larger apically.

Length, 4.75 mm.; width, 2.30 mm. (through widest part).

Type (male) and allotype (female), North East Burma, Kambaiti, elevation 7,000 ft., April 19, 1940, collected by R. Malaise. The extremely wide costal area and undulate outer margins of elytra are distinctive characters. It is the largest known member of the genus.

*Eteoneus confectus*, sp. nov.

Moderately large, elongate-ovate, with vestiture, the outer nervure of costal area strongly costate. Brown to brownish black, the costal area, except marginal nervure and transverse band testaceous, the legs and antennae pale. Rostrum long, brownish, dark at apex, extending almost to apex of sulcus; rostral sulcus not deep, the laminae low, brown, cordate on metasternum. Head smooth, dark brown, without spines; eyes large, transverse, black. Antennae moderately long, smooth, testaceous; segments I and II moderately stout, short, the former slightly longer; III very long, slender; IV wanting.

Pronotum moderately convex, distinctly pitted, strongly narrowed anteriorly; median carinae sharply raised, without areolae; lateral carinae very short, divaricating posteriorly, present only on triangular process. Paranota represented by small lateral projection at humeral angles. Elytra considerably longer than abdomen, jointly overlapping at apex when at rest; costal area broad, triseriate; the areolae moderately large, arranged in regular rows, hyaline, the transverse band just in front of middle formed by colored veinlets; subcostal area dark, triseriate, narrower than costal area; discoidal area large, impressed, dark, extending slightly beyond middle of elytra, widest at middle, there seven areolae deep; nervures dark and the areolae larger distally. Legs rather long, yellowish brown.

Length, 4.00 mm.; width, 1.40 mm.

Type (female) and paratype, Malacca, Perak. One male specimen bearing same locality as type and with head wanting, lacks the transverse band of costal area, but appears to be this species. Differs from *E. vitutis* D. & P. in being shorter, without vestiture, and with much thicker marginal nervure of elytra. The biseriate costal area distinguishes it at once from *peroronus* below.

*Eteoneus peroronus*, sp. nov.

Closely allied to *E. esakii* Drake, but differing from it in having a broader costal area with the marginal nervure strongly costate, and

shorter antennae. Antennae slender, testaceous, the distal portions of third and fourth segments fuscous; segment I very short, slightly longer and slightly stouter than II; III long, slender, slightly more than twice as long as IV, the latter long, slightly thickened and hairy. Elytra broadest in front of middle; costal area rather broad, biseriate, with a broad, brown, transverse band (veinlets) in front of middle; subcostal area broader, mostly dark fuscous, largely four areolae deep. Short, golden vestiture much sparser than in *esakii*.

Length, 3.00 mm.; width, 1.20 mm.

Type (female), Parit Buntar, Malay Pen., *E. sarptus* D. & P., also, has the outer nervure of costal area strongly thickened.

#### *Dictyotingis*, gen. nov.

Head broad, long, rugose, with five tubercle-like spines, the anterior portion projecting forward almost to the apex of first antennal segment. Bucculae very long, open in front. Rostrum very long, extending on venter, the channel open behind. Antennal tubercles large, flattened. Antennae rather long, moderately stout; segment I stouter and longer than II, obconical; II short; III very long, slenderest, not much slenderer than IV, the latter moderately long. Eyes transverse. Pronotum with an elongate, triangular process behind, tricarinate, the lateral carinae almost entirely concealed by the enormous paranotal protuberances; hood moderately large, rather long, inflated, not extending posteriorly and projecting anteriorly over base of head; paranota inflated, forming a large part of the dorsal surface of pronotum. Elytra with distinct areas, very similar to *Cetiocysta* D. & P. in form. Metasternal orifice distinct. Wing present.

Type of genus, *D. gibberis*, sp. nov. This genus is peculiar in certain structures. The head is long, rugose, and projects forward as in certain genera of the subfamily Cantacaderinae Stal, whereas the elytra and pronotum are formed as in certain genera of the subfamily Tingitinae Stal. The bucculae are very long and open in front.

#### *Dictyotingis gibberis*, sp. nov.

Large, broad, brownish, the markings fuscous or black. Head brown, rugose, the spines testaceous, reduced to short, blunt tubercles. Rostrum very long, reaching on the fourth venter; rostral channel gradually widening posteriorly, entirely open behind. Eyes transverse, black. Bucculae long reticulate, narrowed anteriorly, open in front. Middle and hind coxae placed close together, the legs testaceous and mottled with brown spots. Antennae brownish-testaceous, the apical portion of third and fourth segments darker; segment I slightly more than twice as long as II; III nearly three times as long as IV.

Pronotum convex, dark, the triangular process reticulate, brownish; paranota large, inflated, each forming large humeral protuberances which cover most of each side of pronotum, each strongly constricted within near the middle, the areolae large and clouded with dark fuscous, the nervures brown; hood moderately large, compressed laterally, the crest narrow



and located posteriorly, the areolae clouded with brown or black, the nervelets brown; median carinae raised, indistinctly aerolate, more elevated near apex of triangular projection; lateral carinae visible behind pronotal protuberances. Elytra similar to members of the genus *Cetio-cysta* in outline and structure, but with the lateral margins strongly sinuate; costal area moderately wide, considerably clouded with dark fuscous in the widened areas, the areolae at base and between the darker areas largely hyaline; subcostal area wider than costal, with a costate nervure near the outer margin setting off one row of areolae, the areolae within larger and three to four deep; discoidal area very large, bounded by a strongly costate nervure, extending beyond middle of elytra, narrow at base and apex, widest a little beyond middle, six areolae deep; sutural area large, widely reticulated, the areolae of subcostal, discoidal, and sutural areas large, clouded with brown or fuscous. Wings longer than the abdomen.

Length, 5.00 mm.; width, 2.20 mm.

Type (male) and 1 paratype, Madura, India, collected by J. Dubreuil. The pronotal protuberances are differently formed than in the genera *Diplogompus* Mayr., *Diplocysta* Horvath, *Cetio-cysta* Drake & Poor, and *Elasmognathus* Stal. The very long head, long bucculae, long rostrum, and peculiar pronotal protuberances are distinguishing structures.

*Physatocheila orientis*, sp. nov.

Elongate, broad, brown, the costal area with an extremely broad fascia just in front of the middle. Head black, with five moderately long, appressed, testaceous spines. Rostral channel moderately large, the laminae high, reticulate, not meeting behind, the rostrum extending to middle of metasternum. Antennae brown, with last segment largely blackish, moderately stout, moderately slender, without clothing; segment I very short, scarcely longer or stouter than II; III long, slender, slightly more than three times as long as IV.

Pronotum convex, coarsely pitted, tricarinate; lateral carinae slightly divaricating posteriorly; median carina slightly more elevated, all non-reticulate. Hood small, subtruncate in front, inverted V-shaped. Paranota broad, reflexed, and resting on sides of pronotum, covering anterior portion of lateral carinae, faintly inflated at humeri. Elytra widest a little before middle; costal area broad, rather widely reticulate at base (triseriate) and narrower in apical half (biseriate), there the areolae hyaline, much more closely reticulated (quadriseriate) in the extremely long, transverse fascia; subcostal area wide, mostly triseriate; discoidal area large, long, the outer margin sinuate, widest near middle, there about nine areolae deep; sutural area becoming more widely reticulate posteriorly. Legs brown, rather slender.

Length, 4.35 mm.; width, 2.00 mm.

Type (female), Sapporo, Hokkaido, Japan, May 28, 1904, Matsumura; paratype Oguma, Saghalin, Japan. The wide costal area and its long fascia separate this species from other oriental members of the genus. It is very

closely related to *P. 4-maculata* Fieber from Europe and *P. harwoodi* China from England and may prove to be not more than a variety of one of these species.

*Physatocheila civatis*, sp. nov.

Elongate-ovate, shorter and a little broader than *objicis* Drake, grayish brown. Head black, with five short, testaceous spines, the hind pair appressed. Eyes large, black. Antennae dark brown, indistinctly hairy, the last segment blackish; segment I short, stout, a little longer and stouter than II; III slightly bent, three times as long as IV. Rostrum extending beyond middle of mesosternum. Legs moderately long, brownish.

Pronotum moderately convex, finely pitted, sharply tricarinate; carinae non-reticulate, the lateral slightly concave within in front; hood small, areolate; paranota narrow, completely reflexed, triseriate in front and biseriate behind. Elytra with costal area biseriate, the subcostal area mostly biseriate.

Length, 3.30 mm.; width, 0.90 mm.

Type (male), allotype (female), and 3 paratypes, Mt. Wilson, N. S. Wales, Australia, Biro, 1900. This species differs from *P. biseriata* Hacker in having less elevated pronotal carinae, more closely appressed and wider paranota in front; the subcostal area of elytra is also wider.

*Physatocheila objicis*, sp. nov.

Similar to *P. uniseriata* Hacker in size, form, and color, but easily separated from it by the obsolete costal area which is represented by a costate nervure. Head convex above, usually with four or five short, tubercle-like spines, the median often wanting. Antennae brownish, the apical segment subclavata, the terminal segment dark brown to blackish. Rostrum extending to the meso-metasternal suture. Eyes black. Pronotum moderately convex, pitted, sharply tricarinate, the carinae non-areolate, slightly less raised in front, the lateral carinae faintly concave within front. Paranota very narrow, completely reflexed, mostly biseriate. Bucculae testaceous, closed in front, with a tubercle on each side in front. Hood and other characters very similar to *uniseriata*.

Type (male) and allotype (female), Kista, Victoria, Australia, Oct., 1928, collected by F. E. Wilson; paratype, 4 specimens from Australia. The paranota is broader in *uniseriata* and the costal area of elytra entirely uniseriate.

*Physatocheila veteris*, sp. nov.

Moderately large, brown, with indistinct lighter areas. Head black, convex above, with five brown, moderately long spines, the median and hind pair appressed. Eyes long, blackish. Rostrum long, brown, extending a little beyond apex of channel. Legs moderately long, dark brown. Pronotum moderately convex, coarsely pitted, sharply tricarinate; all carinae non-areolate, the median slightly more elevated, the lateral parallel; hood

moderately large, rather low and broad, scarcely produced in front; paranota rather broad, completely reflexed, three to four areolae deep, the outer margins resting on the dorsal surface of pronotum. Elytra broad, narrowed apically; costal area moderately wide, biseriate, the areolae moderately large; subcostal area broad, quadriseriate; discoidal area large, extending considerably beyond the middle of elytra, widest near middle, there seven areolae deep, the outer margin slightly raised and strongly sinuate.

Length, 3.20 mm.; width, 1.45 mm.

Type (male) and paratype (female), Sappora, Hokkaido, Japan, taken by Matsumura. This species is broader, has broader paranota and thicker nervures than *P. fulgoris* Drake. *P. chatterjeei* Drake is a much smaller species, with more sharply raised hood and a shorter rostrum.

*Physatocheila ruris*, sp. nov.

Moderately large, brown, slightly variegated with testaceous atenae dark brown, rather short; segment I short, stout, scarcely longer than II; III twice as long as IV, the latter fusiform. Head black, with five short, brown spines, the median and hind pair appressed. Eyes moderately large, black. Rostrum long, extending to end of sulcus. Body beneath dark brown.

Pronotum moderately convex, sharply tricarinate, the median faintly more elevated, raised anteriorly so as to form a rather long, roof-like hood; paranota rather narrow, completely reflexed, mostly triseriate, the areolae small. Elytra brown, the costal area largely testaceous; costal area not very broad, biseriate; subcostal area a little broader, largely triseriate; discoidal area long, very broad, the outer margin strongly sinuate, widest near middle, seven areolae deep; sutural area becoming more widely areolate apically.

Length, 3.00 mm.; width, 1.20 mm.

Type (female), Krvangtung, Kan-lin San, 700-900 ft., South China, April 24, 1940, collected by J. E. Gressitt and F. X. To.

*Tigava ugandana*, sp. nov.

Head dark fuscous, the frontal spine absent; hind spines long, slender, pale testaceous, nearly reaching anterior margins of eyes. Rostrum testaceous, dark at apex, extending to middle of mesosternum. Bucculae broad, reticulate, black, testaceous behind. Antennae long, rather slender, brownish, indistinctly clothed with fine, short, pale hairs; segment I long, slightly less than four times the length of II, the latter short; IV very long, slightly bent. Eyes large, black. Legs long, slender, testaceous, the tarsi blackish.

Pronotum strongly convex, finely pitted, brownish black, shiny; carinae, collar, paranota, and part of triangular process pale testaceous; median carina distinct, thin, not areolate, the lateral carinae distinctly divaricating and becoming indistinct anteriorly; paranota obsolete, except opposite calli, there very narrow. Elytra testaceous, most of discoidal

area and a very broad inverted V-shaped mark (including a large part of sutural area) dark fuscous; costal area narrow, uniseriate, the areolae small, oblong, and clear, the outer margin broadly concave beyond the middle; subcostal area a little broader, biseriate; discoidal area not reaching middle of elytra, triangular, widest near middle, the outer margin nearly straight. Body beneath black, shiny.

Length, 3.95 mm.; width, 0.90 mm.

Type (male), Uganda, Africa.

*Tigava corumbiana*, sp. nov.

Large, elongate, reddish brown, the carinae, paranota, apex of triangular process, costal area, hind pair of spines of head, legs, rostral laminae, and most of bucculae testaceous. Body beneath reddish brown, the mesosternum and apical portion of abdomen jet black; tarsi dark. Wings smoky, considerably longer than abdomen. Antennae very long, rather slender, brown, the terminal segment almost entirely black. Eyes black, moderately large. Head reddish brown, the vertex with median furrow; frontal spine short, brown; posterior spines long, slender, appressed, extending as far forward as anterior margins of the eyes.

Pronotum moderately convex, the carinae sharply raised and indistinctly areolate; lateral carinae slightly convex within on disc, slightly converging behind; paranota narrow, indistinctly areolate; calli black, smooth. Lateral margin of paranota and elytra finely serrate. Elytra much longer than abdomen; costal area uniseriate, the areolae small, a little larger in widest part. Terminal venter in female bifid at apex, with a rather prominent, transverse ridge a little behind the middle, the ends of ridge raised and distinctly convex below. Last venter in male long, somewhat flattened and sloping dorsally, distinctly bifid at apex.

Length, 4.65 mm.; width, 1.00 mm.

Type (male), allotype (female) and two paratypes, Corumba, Matto Grosso, Brazil. This species is apparently very similar to *T. puchella* Champion, but larger and with the abdomen beneath bicolored. The costal area is wider than in *T. praececellens* Stal. The male and female genital segments have good specific structures in several species of the genus *Tigava* Stal and need to be studied and figured.

*Epimixa roboris*, sp. nov.

Head black, the two frontal spines represented by mere, testaceous tubercles. Eyes large, brownish. Antenniferous tubercles thick, blunt, somewhat testaceous. Antennae with the first two segments dark fuscous, thickened, the first a little less than twice the length of the second, the other segments wanting. Rostrum short, stout, barely reaching mesosternum; rostral laminae low, whitish testaceous, very widely separated on meso- and metasternum. Body beneath black. Legs short, rather stout, brownish, the tarsi and basal portion of femora black-fuscous.

Pronotum pale stramineous, very coarsely pitted, unicarinate; calli black; collar narrow, pale; paranota very narrow, carina-like, barely dis-



tinct behind. Elytra pale stramineous, with nervures separating areas brownish to dark fuscous; costal area uniseriate, the areolae rather large; subcostal area very wide, mostly quadriseriate; discoidal area large, long, extending considerably beyond middle of elytra, widest opposite apex of triangular process, there five areolae deep, the areolae rather large.

Length, 3.65 mm.; width, 1.42 mm.

Type (female) and 1 paratype, Island of Madagascar. The uniseriate paranota and much broader costal area separate this species from *E. alitophrosne* (Kirkaldy) from Australia.

*Tingis veteris*, sp. nov.

Large, very broad, testaceous, some of the veinlets more or less variegated with brown or dark fuscous, moderately clothed with very fine, rather long pale hairs. Head dark, with five stout, porrect, moderately long, testaceous, hairy spines; eyes dark, moderately large. Rostral channel deep, narrow on mesosternum, broader and sub-cordate on metasternum, the laminae testaceous and hairy; rostrum testaceous, dark at tip, extending nearly to the middle of metasternum. Antennae stout, yellowish brown, terminal segment blackish, clothed with rather short hairs; segment I very stout, short, longer than II; III straight, approximately one and one-half times as long as IV, the latter slightly thickened. Bucculae testaceous, hairy, closed in front.

Pronotum moderately convex, coarsely pitted, reticulate behind, brownish, sharply tricarinate, each carina with the areolae becoming slightly larger and distinct posteriorly; lateral carinae long, nearly parallel. Hood moderately large, roof-like, slightly projecting forward at apex. Paranota rather broad, very long, wider in front than behind, rather closely reticulated, six areolae deep in front. Elytra broad, the hairs along the outer margins (also paranota) much shorter than those on nervures separating principal areas and carinae of pronotum; costal area very broad, slightly narrower at middle, rather closely reticulate; the areolae not arranged in very definite rows, mostly five deep, veinlets variegated with fuscous, forming almost a distinct band a little in front of middle; subcostal area much narrower, with three rows of areolae along basal portion, two behind; discoidal area very large, two-thirds of the length of elytra, the outer margin sinuate, widest near middle, there seven or eight areolae deep; sutural area large, the areolae becoming faintly larger apically. Abdomen dark brown beneath, often covered with white exudation, densely clothed with short hairs. Male genital segment broad, the claspers large, strongly curved.

Length, 4.50 mm.; width, 1.10 mm.

Type (male), allotype (female), and paratypes, Province Kianzu, China, collected by Kolthoff. This insect is larger than its congeners from China. It belongs to the subgenus *Tropidocheila* Fieber and resembles *T. amplicata* H.-S. in general aspect but has a stouter antennae, stouter spines on head, and with longer and more conspicuous hairs on carinae and main nervures of elytra. *T. pilosa* Humn. has a differently

formed head, slenderer antennae, and very long hairs on margins of paranota and elytra.

*Esocamphylia hackeri*, sp. nov.

Small, narrow, brownish, with few veinlets partly embrowned. Head brown, moderately convex, with five short, testaceous spines; front pair of spines very short, blunt, porrect; median spine tubercle-like; hind pair appressed, not quite extending as far forward as front margins of eyes. Bucculae long, reticulate, brownish, contiguous in front. Rostral channel deep, the laminae foliaceous, testaceous, open behind; rostrum dark, extending a little beyond meso- metasternal suture. Antennae rather stout, dark brown; segment I stouter and nearly one and one-half times as long as II; III moderately long, two and one-half times as long as IV, the latter enlarged distally.

Pronotum coarsely pitted, slightly convex on disc, sharply tricarinate; hood small, rather flat, scarcely produced in front; paranota reflexed and resting on pronotum, concealing anterior portion of lateral carinae, slightly inflated over humeri; lateral carinae subparallel, indistinctly areolate, the median slightly more raised; triangular process elongate, narrow at apex. Elytra narrowed behind; costal area reduced to a very narrow, reflexed, linear ridge; hypocostal ridge rather wide, uniseriate, appearing almost like a deflected costal area as described by Hacker; subcostal area broad biseriate; the areolae rather large, discoidal area with the inner boundary sharply raised, the outer boundary distinct but not strongly elevated, narrower at base and apex, widest at middle, there five areolae deep, sutural area large, the areolae about the same size as those of discoidal and sutural areas.

Length, 1.25 mm.; width, 0.82 mm.

Type (male) Mt. Lofty Ridge, S. Australia, collected in moss and lichens by N. B. Tindale. This species modifies the generic description of *Esocamphylia* Hacker by the structure of the paranota. A paratype of *E. incarinata* Hacker has the costal area as described above in *hackeri*; the deflected costal area as described by Hacker seems to be the hypocostal ridge of Stal.

*Acalypta sauteri*, sp. nov.

Broadly ovate, brown, the pronotum and costal area of elytra largely yellowish brown. Head dark brown, with two short, porrect, testaceous spines. Rostrum long, extending beyond apex of sulcus. Antennae moderately stout, brownish; segment I short, stout, scarcely stouter than II, the latter slightly shorter; III mostly testaceous, tapering apically, smooth, almost twice as long as IV; IV stout, fusiform, hairy. Legs, brownish; tibiae mostly testaceous.

Pronotum with large, round pits; reticulate, unicarinate, longitudinally raised along the middle, broadly triangulate behind, slightly excavated on each side of hind margin; median carina distinct, without areolae; hood broadly projecting anteriorly, extending to front margins of eyes, reticulate, bluntly rounded in front; paranota rather narrow, largely bi-

seriate, the outer margin slightly rounded. Elytra with boundary between discoidal and subcostal areas sharply elevated, rather closely reticulated; costal area rather narrow, uniseriate; subcostal area very broad, seven to eight areolae deep; discoidal area very large, broad, broadly and sharply rounded at apex, five to six areolae deep.

Length, 1.65–2.00 mm.; width, 1.25–1.75 mm.

Type (short-winged male) and allotype (female), Oayama, Japan, collected by Sauter. The long-winged form is unknown.

*Atheas paganus*, sp. nov.

Very similar to *A. fuscipes* Champion, but distinguishable by the narrower and fuscous color of costal area of elytra. Antenniferous tubercles short, blunt. Rostrum extending a little beyond the pro-mesosternal suture; channel widening posteriorly on mesosternum, wider and with the sides within convex on metasternum, closed behind, the laminae long, black-fuscous in color. Costal area biseriate, tending to be a little narrower than in *fuscipes*, sometimes brownish basally; color of paranota varies from brownish testaceous to fuscous. Other characters very similar to *fuscipes*.

Length, 2.30 mm.; width, 0.95 mm.

Type (male), allotype (female), and 4 paratypes, Vicosia, Minas Geraes, April 14, 1934, taken on *Aeschynomene* sp. This species is closely allied to *A. fuscipes* Champ. and may prove to be not more than a variety of this species. Many specimens, including paratypes, of *fuscipes* have been examined from Mexico, Guatemala, Brazil, Bolivia, and Paraguay. The color of the paranota and costal area in all these specimens is testaceous or whitish and tends to be a little broader, sometimes triseriate in widest part.

*Acysta australica*, sp. nov.

Moderately large, broad, brown, the costal area (save transverse band), paranota, and appendages testaceous. Head brown, the anterior and hind pairs of spines long, testaceous, appressed, the median atrophied. Eyes black. Legs testaceous, the tarsi dark. Segment I of antennae testaceous, slightly stouter and twice as long as II, the others missing. Rostral channel wide on metasternum.

Pronotum finely pitted, strongly and rather sharply, transversely convex through humeri, unicarinate; collar very sharply set off, areolate, truncate in front; paranota narrow, interrupted, represented by a narrow, uniseriate laminae opposite humeri and a narrower, indistinctly areolate ridge opposite constriction behind collar; median carina thin, more sharply raised on collar, terminating in a small, low, inflated area at apex of triangular process. Elytra broad, sharply widened in front; costal area very broad, testaceous, with transverse, brown band (nervelets) in front of middle, with clear areolae, three–four areolae deep in front, four deep and with distinctly larger areolae in widest part; subcostal area much narrower, triseriate, the areolae small; discoidal area moderately large,

extending slightly beyond middle of elytra, the outer margin sinuate and slightly raised along middle, widest behind middle, there six areolae deep; sutural area becoming more widely areolate and testaceous apically.

Length, 2.65 mm.; width, 1.40 mm.

Type (female), National Park, N. S. Wales, Australia, May 28, 1935, H. Hacker.

*Inoma angusta*, sp. nov.

Elongate, narrow, small, armed with numerous rather long, slender, spines. Head brownish ferrugineous, with five long, slender, testaceous-brown spines; hind pair appressed at base, thence directed slightly upwards and obliquely outwards, median spine shorter, directed almost directly upwards, placed as far back as the hind margins of the eyes; front pair very long, appressed. Rostrum testaceous, dark apically, not quite reaching meso- metasternal suture. Antennae long, rather slender, brownish testaceous, the last segment mostly blackish; segment I short, stouter, and a little longer than II; III long, slightly bent, approximately four times as long as IV, the latter subclavate.

Pronotum pitted, moderately convex, truncate in front, tricarinate, reddish brown, the hind process, carinae, and paranota mostly testaceous; paranota very narrow, indistinctly areolate, with seven or eight rather long, sharp spines along the outer margin; collar raised, areolate, the median portion almost hood-like in appearance; carinae sharply raised, indistinctly areolate, with spines on the dorsal margins. Elytra narrow, broadly concave along the other margins behind the middle; costal area narrow, uniseriate, the areolae small, the outer margins spinose; subcostal area wider, triseriate in widest part; discoidal area long, extending considerably beyond middle of elytra, widest in front of middle, there five areolae deep, the boundary armed with erect spines; discoidal area largely testaceous, the areolae becoming a little larger apically. Legs long, rather slender, testaceous-brown, the tarsi blackish.

Length, 2.50 mm.; width, 0.75 mm.

Type, macropterous (male), Dorrizo, N. S. Wales, Australia, H. Hacker, collector. This insect differs from *I. multispinosa* Hacker by its longer and much more slender body, long legs and antennae, smaller hood, and much narrower paranota and costal area. The spines are also slenderer and the carinae less elevated. *H. multispinosa* is a shorter and broader species, strikingly marked with pale testaceous. The latter is represented by both long- and short-winged forms in my collection.

*Amblystira solida*, sp. nov.

Very similar to *A. peltogyne* D. & H. but distinguishable by the much longer posterior spines, more convex head and longer rostrum. Head black, convex above; hind pair of spines testaceous, stout, long, appressed, extending to base of antenniferous process, median and front pair of spines rather short, testaceous, turned downward. Antennae long, testaceous, the apical segment mostly black; segment I stouter and nearly



three times the length of II; III nearly twice as long as IV, the latter very long. Rostrum not quite reaching meso-metasternal suture.

Pronotum strongly convex, the lateral carinae not very distinct; collar raised, prominent, areolate; median carinae distinct; slightly more raised on posterior process. Elytra constricted behind the middle; costal area a little narrower than in *peltogyne*; sutural area with a very broad, inverted Y-shaped, black-fuscous mark. Other characters very similar to *peltogyne*.

Length, 3.55 mm.; width, 1.00 mm.

Type (female) and 2 paratypes, Guaruja, Brazil, Sept. 5, 1939, J. C. Hambleton, collector.

*Amblystira socia*, sp. nov.

Small, black, the widest part of costal area testaceous. Legs comparatively short, testaceous, the tarsi dusky. Antennae testaceous, the apical half black-fuscous; segment I short, a little longer and stouter than II; III long, slender, straight, indistinctly pilose, nearly twice as long as IV; IV long, slender, with longer hairs. Body beneath black, a little shiny. Rostrum testaceous, barely reaching meso-metasternal suture; laminae black, low, widely separated on meso- and metasternum. Wings a little longer than abdomen, smoky in color.

Head black, the hind pair of spines very short, black. Eyes large, blackish, transverse. Pronotum strongly convex, deeply pitted, tricarinate; paranota represented by a very narrow carina; lateral carinae distinct, not as high as median, converging posteriorly; collar raised, distinct black. Elytra widest opposite apex of triangular process; indistinctly serrate along the costal margin; costal area narrow, wider beyond apex of sutural area, there testaceous and uni- or biseriate, the areolae hyaline; uniseriate along basal portion, there narrow and the areolae small; subcostal area wide, widest opposite apex of sutural area, there four or five areolae deep; discoidal area triangular in outline, distinctly raised apically, not reaching middle of elytra; sutural area more widely reticulated apically, there fuscous and with some of the areolae not entirely clouded; small areolae of costal, subcostal and discoidal areas whitish.

Length, 2.25 mm.; width, 0.90 mm.

Type (male), allotype (female), and 2 paratypes. Chaco, Paraguay.

This insect may be distinguished from *A. silvicola* Drake by its much smaller size, shorter legs, and antennae. In both species the discoidal area is distinctly elevated apically, whereas in *A. opaca* Champ. it is flat. Two examples from Mercedes, Costa Rica, Aug. 5, 1928, seem to belong to this species. The latter have the apical three-fourths of the last antennal segment black-fuscous.

*Amblystira solida*, sp. nov.

Very similar to *A. fuscitarsis* Champion, but readily separated from it by the broader elytra at base, more rugose pronotum, and shorter triangular process of pronotum. Head black, without spines. Eyes black.

Paranota black, slightly rugose, pitted, strongly narrowed anteriorly, tricarinate; lateral carinae not very distinct; median carina distinct, obsolete on apical portion of triangular process; collar distinct, broader than in *fuscitarsis*. Elytra marked similar to *fuscitarsis*, widest near base; costal area widest along basal portion, there biseriate, uniseriate from anterior margins of transverse fascia posteriorly, the areolae largest opposite apex of discoidal area; subcostal area triseriate, the nervures mostly black, testaceous behind; discoidal area with black nervures, not reaching middle of elytra, widest behind middle, subrounded at apex; sutural area broad, the nervures mostly dark fuscous. Other characters similar to *fuscitarsis*.

Length, 2.20 mm.; width, 0.90 mm.

Type (female), Hinche, Haiti, Jan. 15, 1930.

*Corycera fortis*, sp. nov.

Small, dark fuscous, the head and most of pronotum black; paranota and costal area pale testaceous. Legs long, slender, testaceous. Antennae rather long, slender; segment I moderately long, dark brown to fuscous, stouter and a little less than twice as long as II, the latter pale testaceous; III pale testaceous, slightly more than three times as long as IV; IV rather long, slender, testaceous, the apical half dark fuscous. Rostrum testaceous, reaching middle of mesosternum. Head with five long, blackish spines; hind pair long, appressed, nearly reaching antenniferous processes; median and anterior spines very long, directed forward in one group, extending as far forward as the apex of first antennal segment.

Pronotum convex, pitted, sharply tricarinate, the lateral carinae slightly converging posteriorly; triangular process brownish, areolate; collar distinct, raised anteriorly; paranota moderately wide, uniseriate; the areolae a little smaller than those along basal portion of costal area. Elytra with outer margins concave beyond the middle; costal area moderately broad, uniseriate, a couple extra areolae in widest part, some of the transverse veinlets along the basal portion infusate; subcostal area broad, three areolae deep; discoidal area reaching middle of elytra, widest beyond middle, there four or five areolae deep, narrowed and scarcely raised at apex.

Length, 2.25 mm.; width, 0.85 mm.

Type (male) and allotype (female), Chaco, Paraguay. This species is most closely related to *C. comptula* Drake but readily separated by the shorter frontal spines, and wider costal area. In *comptula* the apex of discoidal area is distinctly raised; the rostrum nearly extends to the base of mesonotum. *Corycera* (*Gelchossa*) *albocosta* (Drake) is similar in appearance but is longer, without median frontal spine and fuscous basal segment of antennae.

*Corycera vallis*, sp. nov.

Closely allied to *C. rugulosa* Drake, but easily separated from it by the shorter first antennal segment, the atrophied median, and the greatly reduced frontal spines. Head black; hind pair of spines short, blunt,

appressed, about reaching middle of eyes, brownish; median spines wanting or very much reduced; front pair of spines short, turned inwards; eyes rather large, black. Antennae long, slender, smooth; segment I stout, black, rather long, slightly more than twice as long as II and much stouter; II testaceous, short; III long, very slender, testaceous, straight, two and one-half times as long as IV; IV long, slender, with pale hairs, mostly black. Rostrum testaceous, dark at apex, not quite reaching middle of mesosternum. Body beneath black. Legs slender, long, testaceous, the tarsi darker.

Pronotum slightly rugose, black, convex, coarsely pitted. Paranota and costal area slightly narrower than in *rugulosa*. Other characters and color pattern very similar to *rugulosa*, perhaps slightly darker.

Length, 2.65 mm.; width, 1.00 mm.

Type (male), allotype (female), and 20 paratypes, Horqueta, Paraguay, 1938. The median frontal spine in *rugulosa* is very long and stout and the first antennal segment only about two-thirds as long as in *vallaris*. *C. separata* D. & H. is also a very closely related species. The latter has much shorter first antennal segment and broader paranota; costal area is much wider and testaceous, the eyes smaller.

*Leptodictya galerita*, sp. nov.

Very similar to *L. sodalatis* Drake, but broader, and with the hood much larger, about two and one-half times as high. Head strongly convex above, with five extremely long, slender, testaceous spines, the apical three-fourths black-fuscous. Hood high, strongly compressed laterally, projecting slightly over the basal portion of the head; median carina slightly more raised anteriorly, uniseriate, the areolae larger than in *sodalatis*. Elytra broad, the tips rather widely separated when at rest; costal area broad, the outer margin somewhat rounded and beset with short hairs. Color, markings, and other characters very similar to *sodalatis*.

Length, 4.35 mm.; width, 2.50 mm.

Type (male), Horqueta, Paraguay, 1938. *L. evidens* Drake is a much smaller species and has a differently formed paranota. The paranota of *L. leinahoni* Kirk., *L. solita* Drake, and *L. sodalatis* are very similar, but otherwise very different.

*Oedotingis* Drake, gen. nov.

Separated from *Australotingis* Hacker by the paranota, carinae hood, and discoidal area of elytra. Head not concealed from above by the hood, the three frontal spines correct, the hind pair appressed. Nervures, especially those of the head, paranota and median carina, clothed with very fine, long hairs. Paranota completely reflexed, inflated, the outer margin resting on the sides of the pronotum but not concealing the lateral carinae. Hood moderately large, covering basal portion of head. Pronotum convex, pitted, tricarinate. Antennae long, moderately slender. Elytra sharply widened at base, the tips separated; costal area broad, with impressed,

darkened, oblique nervures; discoidal area extending beyond middle of elytra.

Genotype, *Australotingis williamsi* Drake, from Ecuador. In many respects *Oedotingis* resembles some of the larger and more conspicuously marked species of the genus *Leptodictya*. It may, however, readily be separated from this genus by the bullate paranota.

***Leptopharsa ruris*, sp. nov.**

Similar in appearance to *L. tenuis* (Champ.) but with shorter antennae and elytra and with the rostrum scarcely reaching base of mesosternum. Head black, with five long, slender spines, the hind pair and median very long. Antennae long, slender, testaceous, the first and most of fourth dark fuscous to black; segment I moderately long, stouter and approximately two and one-half times as long as II, the latter short; III very long. Rostral laminae whitish testaceous, the rostrum testaceous, not quite extending to meso- metasternal suture. Bucculae whitish, testaceous. Eyes black. Legs testaceous, the tips of tarsi dark.

Pronotum moderately convex, pitted, black, somewhat shiny, tricarinate, the carinae, paranota, hood, and hind triangular projection whitish testaceous; other structures very similar to *tenuis*. Elytra with sides nearly parallel, broader and shorter apically than in *tenuis*, the discoidal area also a little broader; costal area biseriate, the areolae moderately large; color and markings very similar to *tenuis*.

Length, 2.34 mm.; width, 0.95 mm.

Type (male), allotype (female), and 8 paratypes, Antiqua, British West Indies, Sept. 26-28, 1931. The carinae, hood, and paranota are very similar to *tenuis*. The elytra are also a little broader, shorter, and not completely overlapping posteriorly when at rest.

***Stephanitis aucta*, sp. nov.**

Large, the elytra divaricating apically and with their tips widely separated; testaceous, the pronotum ferrugineous. Pronotum strongly convex, coarsely pitted, tricarinate; lateral carinae long, foliaceous, unicarinate, testaceous, extending from just behind calli to base of triangular process, distinctly constricted a little before base, the areolae moderately large; median carina very high, long, longer than hood and fully as high, mostly biseriate, the areolae very large; hood large, strongly inflated, extending as far forward as the apex of the head, somewhat pyriform in shape, nearly twice as long as high. Rostrum very long, reaching on second venter; rostral channel wide, the laminae moderately high, uniseriate, entirely open behind. Paranota very large, very wide, strongly reflexed, largely quadriseriate, the outer row of areolae much larger than others, extending nearly as high over pronotum as crest of hood. Triangular process long, membranous, triangular, areolate, testaceous.

Antennae extremely long, very slender, shortly pilose, testaceous, most of terminal segment black; segment I extremely long, narrowed apically, widened at apex, five times as long as II, the latter short; III long,



not very much longer than IV, the latter extremely long, scarcely thicker and all but basal portion black. Elytra strongly divaricating posteriorly, the outer margins (also paranota) indistinctly serrate; costal area very broad, five areolae deep in widest part, the areolae large; discoidal area very short, the outer boundary raised jointly with subcostal area and rounded. Legs testaceous, very long and slender.

Length, 4.80 mm.; width (through apex of triangular process) 2.85 mm.

Type (female), Chapoda, Brazil. Readily separated by its size, the long legs, rostrum, and antennae, and the strongly divaricating elytra.

**Tanybyrsa**, gen. nov.

Head short, the bucculae closed in front. Antennae moderately long, slender; segment I short, longer than II; III longest, slenderest; IV moderately long, slightly thickened. Rostral channel not interrupted. Hypo-costal ridge uniseriate. Orifice present. Pronotum convex, pitted, tricarinate; the triangular process reticulate; hood small, inflated, scarcely produced in front; paranota considerably reflexed, areolate, not very broad. Margins of elytra, paranota, carinae, and principal nervures of elytra fringed with hairs. Elytra broad, much wider than pronotum, divided into the usual areas, the discoidal area large, extending nearly to or a little beyond middle of elytra; discoidal and sutural areas raised, on approximately the same level.

Genotype *Compseuta secunda* Hacker.

This genus contains two species described by Hacker as *Compseuta secunda* and *C. ampliata*. The elytra are without tumid elevations.



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# METABOLISM OF THE LACTIC ACID BACTERIA, PARTICULARLY *BACILLUS DEXTROLACTICUS*<sup>1</sup>

ARIEL ANDREW ANDERSEN

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The nutritional requirements of heterofermentative and homofermentative lactic acid bacteria were investigated, and the fermentative metabolism of *Bacillus dextralacticus* studied. The cultures of lactic acid bacteria employed include four heterofermentative and three homofermentative species. Among the latter is a member of the genus *Bacillus* which was isolated during the course of the work. Although it is a spore-former, it is a homofermentative lactic acid form by definition. Because of its simple growth requirements and vigorous production of dextralactic acid, the organism was carefully studied and described. Since it could not be identified with any other species, it was recognized as a new species and named *Bacillus dextralacticus*.<sup>2</sup>

## NUTRITION OF HETEROFERMENTATIVE LACTIC ACID BACTERIA

Nutritional studies of four cultures of heterofermentative lactic acid bacteria, *Lactobacillus mannitopoeus*, *L. buchneri*, *L. lycopersici* and *Streptococcus paracitrovorus*, were undertaken to determine the requirements of the group. Although the four cultures vary somewhat, they are probably representative of the group. Malt sprouts constitute a rich source of food material for these cultures. When water alcohol, and ether extracts of malt sprouts were tried, only the water extract contained the essential material for growth of these cultures in a protein-free and amino acid-free medium. The alcohol extract contained the essential material when added to a basal medium containing hydrolyzed casein. The ether extract of either the malt sprouts or the alcohol extract was not effective. The "Neuberg precipitate" of the alcohol extract was effective, whereas the "Neuberg filtrate" was not.

The alcohol extract of malt sprouts was replaced by ether extract of acidified yeast extract, thiamin, and riboflavin. In a basal medium containing hydrolyzed casein, the ether soluble factor of acidified yeast extract was essential for all four cultures; tryptophane was essential for good growth of *S. paracitrovorus* and *L. buchneri* but was not essential for *L. mannitopoeus* and *L. lycopersici*; riboflavin and thiamin stimulated growth of cultures *L. mannitopoeus*, *L. lycopersici*, and *S. paracitrovorus*, but neither was essential in the presence of the other, although some stimulation was shown; when thiamin and riboflavin were omitted from the medium, *L. mannitopoeus*, *L. lycopersici*, and *S. paracitrovorus* were completely stopped, while *L. buchneri* was not substantially affected.

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 649.

<sup>2</sup> Andersen, A. A., and C. H. Werkman, 1940. Description of a dextro-lactic acid forming organism of the genus *Bacillus*. Iowa State College Jour. Sci. 14:187-94.

In all cases growth as measured by acid production was considerably reduced when the alcohol extract of malt sprouts was replaced by the ether-soluble factor of acidified yeast extract, thiamin, riboflavin, and tryptophane.

Hydrolyzed casein was completely replaced by nineteen amino acids. In the amino acid medium the addition of pantothenic acid showed no stimulation.

#### NUTRITION OF HOMOFERMENTATIVE LACTIC ACID BACTERIA

The nutritional requirements of three cultures of homofermentative lactic acid bacteria, *Lactobacillus delbrueckii*, *L. helveticus*, and *Bacillus dextralacticus* were investigated. The study showed that *B. dextralacticus* was very different in nutritional requirements from the other two organisms. Malt sprouts constituted a rich source of nutrients for all three species. The active material was readily extracted with water. The alcohol extract of malt sprouts added to a basal medium of glucose 1 per cent, sodium acetate 0.6 per cent, ammonium sulfate 0.3 per cent, and Speakman's inorganic salt mixture, did not support growth of the cultures unless it was supplemented by hydrolyzed casein. The ether extract of malt sprouts added to the basal medium containing hydrolyzed casein, did not support growth of *L. delbrueckii* or *L. helveticus*, but did *B. dextralacticus*. The last organism grew poorly on the basal medium when hydrolyzed casein was added to it, while *L. delbrueckii* and *L. helveticus* did not grow. All three organisms in the basal-hydrolyzed casein medium were stimulated by the ether insoluble fraction and the "Neuberg precipitate" of the alcohol extract of malt sprouts. The ether-soluble fraction of the alcohol extract did not stimulate growth of any of the cultures. The "Neuberg filtrate" was effective for *B. dextralacticus* but not for *L. delbrueckii* and *L. helveticus*. Malt sprouts in addition to nutrients appear to contain an inhibitor which is not present in the "Neuberg filtrate."

In a basal medium containing water extract of gluten, all three cultures demonstrated ability to utilize ammonium sulfate, particularly when the protein nitrogen was low.

*B. dextralacticus* grew well in the basal medium containing the ether extract of acidified yeast extract plus thiamin; *L. delbrueckii* and *L. helveticus* failed even though riboflavin, tryptophane, and hydrolyzed casein were also added.

Further work on *B. dextralacticus* revealed that the ether-soluble factor could be replaced by hydrolyzed casein and this by amino acids. Cystine, arginine, methionine, glutamic acid, and threonine were essential or beneficial. Riboflavin replaced thiamin, one or the other was necessary, but not both. Certain amino acids appeared to have an inhibitory effect.

Growth of *L. helveticus* was obtained in the basal medium plus ether extract of acidified yeast extract, thiamin, riboflavin, tryptophane, hydrolyzed casein, and pantothenic, ascorbic, thioglycolic, and indole-3-acetic acids. *L. delbrueckii* failed in the same medium. *L. helveticus*, after nine transfers of poor growth, was transferred to an amino acid medium con-

sisting of basal, thiamin, riboflavin, the ether soluble yeast factor, and nineteen amino acids. There was an immediate marked stimulation.

#### FERMENTATIVE METABOLISM OF *BACILLUS DEXTROLACTICUS*

The optimal conditions for lactic acid formation by *Bacillus dextrolacticus* were determined. Several sources of nutrients and mineral requirements and certain environmental conditions were studied.

Soybean meal, 1 gram per 100 ml., was found to satisfy the nutritional requirements of the culture for a 15 per cent glucose fermentation when 0.06 gram phosphate, and 0.3 gram ammonium sulfate were added per 100 ml. medium. The addition of these inorganic constituents was vital to the fermentation. Aeration was found to be very essential. The process converted 15 per cent glucose solution to dextrolactic acid in four to five days with a yield of 92 to 95 per cent. Other products occurring in small amounts or traces were 2, 3-butylene glycol, acetylmethylcarbinol, acetic acid and ethyl alcohol.

Steep water residue, corn meal, distillers grains, malt sprouts, and hydrolyzed casein plus thiamin were substituted in the medium for soybean meal. Steep water residue gave a more rapid fermentation than soybean meal. The other substances gave slower fermentations. Hydrolyzed casein 0.3 gram plus 1 microgram thiamin fermented 12 grams of sugar per 100 ml. of medium in 124 hours.

Yeast extract was found to be an excellent source of nutrient. When 1 per cent yeast extract was substituted in the medium for soybean meal, only one-third as much time was required to complete the fermentation, and aeration was found to have but little effect. At 0.4 per cent yeast extract the effect of aeration was more significant.

Yeast extract was fractionated by successive extractions with ether, acetone, alcohol, and water. Each of the fractions supplied sufficient nutrient for a good fermentation except in the case of the ether soluble fraction which required the addition of thiamin. The other fractions probably contained it. Aeration of the fermentation was more necessary with each of the fractions than with the whole yeast extract. The combined fractions gave a more rapid fermentation when the ether soluble fraction was omitted.

The yield of lactic acid was somewhat lower in aerated media. The addition of thiamin to a medium containing the ether-soluble fraction increased the yield of lactic acid from 72.5 to 88.0 per cent in the aerated and 85.5 to 95.6 per cent in the nonaerated. Thiamin appears to be an essential in the formation of lactic acid.

Aeration of the fermenting medium has a nullifying effect on the inhibitory action of cystine and possibly other substances.

## SOME STUDIES ON THE REACTION MECHANISM OF PACK CARBURIZATION<sup>1</sup>

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In this study of pack carburization two fairly independent phases of the mechanism of carburization have been investigated. One of these investigations deals with the direct action of carbon and iron, or carburization at pressures approaching a true vacuum. The other part of the work is a result of a study of the part played by small amounts of water vapor in ordinary pack carburization.

The charcoal used in this work was prepared by thermal decomposition of C. P. dextrose. The samples used for the quantitative work on carburization were cut from  $\frac{3}{8}$ " cold drawn squares of 0.173 per cent carbon steel. All surfaces of the samples were cleaned by grinding on the side of a No. 30 Oxaluma wheel and by washing in alcohol and in ether. The samples weighed approximately 13 grams each.

The first part of the low pressure work was a study of the effect of various reduced pressures on carburization. The pressure in the system was varied from atmospheric to the "vacuum" pressures described below. Eleven different pressures were used with a carburizing time of four hours at 950° C. Each sample was furnace cooled under the pressure of its run. It was found that the amount of carburization increased as the pressure was reduced, the largest rate of increase with change of pressure occurring at a pressure of about 12 mm. For example, the increase in weight at atmospheric pressure was 12.5 mg.; at 44 mm., 25.1 mg.; and at 12 mm., 42 mg. The amount of carburization was at a maximum and almost constant for pressures between 5 mm. and the vacuum pressure, the average gain in weight for this pressure range being about 51 mg. The cases obtained at these pressures (5 mm. to vacuum pressure) were normal and exhibited definite hypereutectoid, eutectoid, and hypoeutectoid structures.

The "vacuum" carburization was studied by varying the time, with temperature constant. In the first study, times at 950° C. were zero; 1 hour, 10 minutes; 4 hours; 8 hours; and 16 hours. The zero time was run by making a regular vacuum run up to 950° C. and then turning off the heating current. Very slight carburization (weight increase, 1 mg.) was obtained for the zero time; only 27.5 mg. increase for the 1 hour, 10 minutes; while weight increases of 63.8 and 83.8 mg. were obtained for the 8-hour and 16-hour runs respectively. The case depths increased in a regular manner with time, being 0.04 mm. at zero time and 2.9 mm. for the 16-hour run. The pressures at the end of the 8-hour and 16-hour runs were 8 microns and 5 microns, respectively. In studying the effect of temperature, the "vacuum" carburizations were run for 4 hours at 50° intervals from 800°

<sup>1</sup> Original thesis submitted December 16, 1941. Doctoral thesis number 659.



to 1,000° C. The carburization was found to increase in a normal manner with an increase in temperature, the increase in weight at 800° C. being 2.1 mg. while at 1,000° C. it was 74.5 mg. The total case depths at 800° and 1,000° C. were 0.14 mm. and 1.85 mm., respectively.

The above investigations at the "vacuum" pressures showed that very slight carburization occurred during the heating and cooling period; that the amount of carburization increased with time and temperature; and that the carbon penetration took place at very low pressures (5-10 microns). Experiments in which other steels, carbonyl iron, other vitreous containers, other sugar carbon, spectrographic carbon, and highly polished surfaces were used showed that the "vacuum" carburization was not inherent with the experimental conditions used. It was necessary to remove the outer surfaces of the steel, and to have it clean, in order to get the reproducible quantitative results reported above. If the original surface was used, very little penetration took place.

In the investigations at various pressures, the total carbon penetration (i. e. case depth to the core) was approximately the same, even though the amount of carbon entering varied from 12.5 mg. to 53 mg. It has been suggested that perhaps a gas such as hydrogen, oxygen, nitrogen, or carbon dioxide may aid in the carbon diffusion at the higher pressures. At the low pressures the gas is removed and the penetration is due only to the increased carbon gradient. This explanation is only in the form of an hypothesis and suggests the need of considerable experimental verification.

There is considerable controversy among metallurgists concerning the effect of moisture in the carburizing compound. Many claim that the presence of small amounts of moisture lead to soft spots in the case. Others state that they have never been able to trace soft spots to absorbed moisture in the carburizing compound. The various theories that have been presented to explain energizer action make no mention of the effect of moisture. Because of this omission, the controversy among metallurgists, and the fact that, unless extreme care is taken, there will always be small amounts of moisture present, the investigations on the effect of moisture were carried out.

Two different packs were used; one being the prepared charcoal alone, and the other this charcoal with 15 per cent barium carbonate added. The carburization was studied at various temperatures from 800° to 950° C., using dry air and air saturated with water vapor at room temperature (25.2 mm. H<sub>2</sub>O). The time at temperature was 4 hours. In making the dry air determinations using plain sugar charcoal alone, the desired temperature was reached under reduced pressure, and then dry air was admitted to the system. Dry air was then passed through the pack at the rate of 0.3 ml. per minute. The samples were furnace cooled under the conditions of the run. For the saturated air investigations the system was flushed with air which had been bubbled through distilled water. The saturated air was then passed at the rate of 1.5 ml. per minute through the pack for 9 hours before the heating was started. During the heating period,

the time at temperature, and the cooling period, the rate of flow was reduced to 0.3 ml. per minute. The runs in which the energized pack was used were made in the same manner, except when dry air was used the pressure was not reduced until the desired temperature was reached.

The results with the unenergized pack showed that the samples run at 950°C. and 875°C. using air saturated at 25°C. showed, on the average, about 1 mg. greater gain in weight than samples run at the same temperature using dry air. The cases obtained with the saturated air showed slightly less ferrite extending to the edge of the samples than did the cases obtained using dry air. The samples run at 800° C. were decarburized, the amount of decarburization not being affected by the moisture content of the air.

With the energized pack, the samples run at 950°, 875°, and 800° C. using saturated air showed about 1 mg. greater gain in weight than the corresponding samples obtained when using dry air. No difference in case characteristics were noticeable. The carburization obtained at 950° C. with the energized pack was comparable with that obtained at the same temperature with the "vacuum" pressures. From the results obtained it is concluded that water vapor up to 25.2 mm. has very little effect in pack carburization.

# PRODUCTION OF THE RING-NECKED PHEASANT (*PHASIANUS COLCHICUS TORQUATUS* GMELIN) IN NORTH-CENTRAL IOWA<sup>1</sup>

THOMAS SEBREE BASKETT

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The purposes of this investigation were (1) to extend the knowledge of behavior of the pheasant (*Phasianus colchicus torquatus* Gmelin), (2) to study the nesting cycle of the pheasant in north-central Iowa, and (3) to determine, as far as possible, the relationships between natural pheasant production and agricultural practices, weather, and other environmental conditions in north-central Iowa.

Research was carried out during the breeding seasons of 1939, 1940, and 1941, on a 1,520-acre portion of the Winnebago Research Area in Winnebago County, Iowa. Lying within the Wisconsin drift area, the 1,520-acre plot is level or moderately sloped, except for two relatively high ridges. About 90 per cent of the land is put to direct agricultural use, and thus the pheasants are forced to adjust themselves to intensive agriculture.

During the winter, pheasants tend to band together in marshes, groves, and other heavy cover. With the advent of spring, their distribution in space becomes more nearly uniform, and males are no longer gregarious. Accompanying these changes, phenomena such as crowing and a kind of territoriality come to notice.

"Crowing stands" were studied in detail. It appeared that the males did not require the presence of particular objects such as stones, while crowing. However, the birds were at least locally prominent during the act.

Although certain male pheasants were observed to appear in the same places day after day, the choosing of unplastic and strictly delimited territories or crowing areas which the males constantly defended against invasion is regarded as questionable. It is felt that the matter of territoriality in the pheasant needs closer scrutiny under north Iowa conditions of large fields and dense populations of the birds.

The male/female ratios were estimated to be as follows: 1:2.4 in 1939, 1:2.1 in 1940, and 1:2.0 in 1941. There was no evidence of greatly lowered egg fertility because of low male/female ratios during the three years.

The earliest nest found was begun in the two-week period, March 16-31, 1939. The latest nest observed was established during the first half of August, 1940. New eggs generally appeared in nests at a rate slightly lower than one per day, but exceptions were noted when the females collaborated in the deposition of clutches.

While female pheasants were incubating, they were seldom seen off the nests. No regular "rest periods" were noted, although the birds were sometimes away from the nests at about 7:00 A. M. The degree of dis-

<sup>1</sup> Original thesis submitted March 16, 1942. Doctoral thesis number 675.

turbance to incubating females by the observer was capable of regulation through the manner of approaching the nests.

During the three years location data were obtained for 533 pheasant nests, and other data were obtained for varying numbers of these nests. Nests were found by repeated systematic patrolling of fields, and by checking in all hayfields and small grain fields as soon after removal of cover as possible.

A tendency for nests to be placed at least proportionally near edges was noted, and there was indication that this tendency was weakened as nesting density increased.

Nests were situated in a wide variety of cover types, but hayfields, small grain fields, and fence rows harbored the largest numbers. Hayfields contained from 34.6 to 64.8 per cent of all nests; small grains, from 19.5 to 22.9 per cent; and fence rows held from 6.6 to 25.3 per cent of the nests.

Percentages of success for all nests found during the three years were as follows: 1939, 37.5 per cent; 1940, 25.4 per cent; and 1941, 23.3 per cent. The proportion of nests successful in small grains was high (40.3 to 80.0 per cent); in fence rows, low (4.8 to 21.1 per cent); and in hayfields, intermediate (20.3 to 34.6 per cent). Nests in types of hay mowed late had higher percentages of success than those in types of hay mowed early. For example, mowing of native hay followed the first mowing of alfalfa by 10 to 14 days, and a higher proportion of nests was usually successful in native hay than in alfalfa.

Losses of nests were attributed to many causes, of which desertion, predation, injury to female, and death of female were the important types. Nearly a third of all nests lost were deserted as a result of disturbance by man in pursuing agricultural activities. Eastern crows (*Corvus brachyrhynchos brachyrhynchos*) were the most destructive predators, probably having caused losses of 19.0 per cent of all destroyed nests. Other known egg predators included ground squirrels (*Citellus* spp.), skunks (*Mephitis mephitis*), weasels (*Mustela* spp.), domestic cats, dogs, and pigs, and man.

Attempts were made to correlate meteorological data, dates of first field work, dates of mowing of hay, and dates of harvesting small grain for the three years. However, no one growing season was sufficiently advanced to cause the carrying out of all the named agricultural practices consistently earlier during one year than during another.

It appeared that there is a basic rhythm of nest-establishment which results in direct procedure of nest-establishment to a peak; beyond the peak the basic rhythm is obscured by renesting. The course of renesting, in turn, is affected by the nesting failure caused by any agent whatsoever.

Through gross analysis, no relationship of nesting success in hayfields to the adjustment between mowing time and seasonal progress of nesting was demonstrated.

Nesting losses are not so grave a matter as they may seem, for, as pointed out by workers, many hens renest until they bring off a brood.



Failure of individual nests does not necessarily signify absolute reproductive loss.

It was estimated that in 1939, 352 chicks hatched and left the nests on the 1,520-acre study area; for 1940 the estimate was 528, and for 1941, 954. During the first seven weeks after hatching, there were losses of about 2.6 chicks per brood in 1939, 3.3 chicks per brood in 1940, and 3.3 chicks per brood in 1941. The following estimated numbers of chicks attained the age of seven weeks: in 1939, 247; in 1940, 355; and in 1941, 588.

The estimates of production derived from nesting data agree rather closely with enumeration data taken before and after the nesting seasons. However, there is some question of the validity of the comparison, because it was necessary to assume the ratio of nests found to total nests in derivation of the production estimates, and because the methods of enumeration (repeated total counts over the nest-research area in the spring; flushing counts during the hunting season and roadside counts in the fall) are subjective.

# A STUDY OF SOME MICROORGANISMS SURVIVING WATER CHLORINATION<sup>1</sup>

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Triplicate samples of chlorinated water from four midwestern and two eastern cities were collected weekly over an eight-month period beginning January 5, 1940. One sample was examined immediately at the water plant laboratory, and the other two were shipped uniced after dechlorinating to Ames, Iowa, or Belleville, New Jersey. Immediately upon arrival at the laboratory one of the shipped samples was examined according to the procedure outlined in "Standard Methods for the Analysis of Water and Sewage," 8th edition, duplicate portions being inoculated into lactose broth and incubated at 37° C. and 28° C. Counts were made on agar using duplicate 5 ml. and 1 ml. portions after 24 and 48 hours incubation at 37° C. After the collection of the first 17 to 20 samples, the procedure was amended to include preliminary enrichment in tryptose lauryl sulfate as well as lactose broth. Confirmation of the positive presumptive tubes was attempted, employing E.M.B. and MacConkey's agar, and brilliant green lactose bile (2 per cent).

The remaining shipped sample was placed in a 28 to 30°C. incubator for 48 hours. At the end of the storage period this sample was examined according to the same procedure employed with the fresh sample with the exception that counts were not made on agar.

The solid confirmatory media and nutrient agar plates yielded 704 lactose nonfermenting cultures. These cultures, upon purification and selection to avoid meaningless duplication, yielded 223 strains for the detailed study. On the basis of morphology, 4 *Sarcina* and 19 *Micrococcus* strains were obtained. The remaining bacilli, according to biochemical activity, were classified into 111 *Pseudomonas*, 8 *Flavobacterium*, 1 *Shigella*, 8 *Proteus*, and 72 *Achromobacter* strains.

An attempt was made using "Bergey's Manual of Determinative Bacteriology," 5th edition, to identify on a species basis the cultures assigned to each genus. All of the *Sarcina* cultures were identified as belonging to three species, but only ten strains of the micrococci corresponded to any of the species listed.

Among the chromogenic organisms, those producing a water insoluble pigment were assigned to the genus *Flavobacterium*, and were found to consist of three species previously described in addition to two groups not listed in "Bergey's Manual." The *Pseudomonas* group, comprising the water soluble, fluorescent, pigment-producing bacteria, was found to consist of six known species as well as seven distinct groups not previously listed.

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<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 697.

All of the *Proteus* cultures were classified as probably *Pr. ichthyos-mius*.

Eight groups not listed by Bergey *et al.* and seven species described by them were found to constitute the *Achromobacter* group. Several strains resembling *Eberthella* and *Shigella* on the basis of morphology and sugar reactions were assigned to this group because they did not reduce nitrates and were not agglutinated by the proper sera. The single strain assigned to *Shigella* resembled *Sh. ceylonensis*, but the 1:100 and 1:500 dilutions of polyvalent Flexner or the 1:250 dilution of Shiga sera did not produce any agglutination.

Although high chlorine residuals for long periods of time (0.5 to 1.0 p.p.m. av. Cl. after 48 to 72 hours exposure) did not prevent the appearance of the lactose nonfermenting bacteria, the latter appeared less frequently in the portions incubated at 37°C. than in those incubated at 28° C. For the purpose of keeping the noncoliform types to a minimum, it is recommended that the temperature used for the bacteriological analysis of water be maintained at 37°C. and not be lowered to 30° C.

Nutrient broth and  $\text{NH}_4\text{Cl}$  were compared as sources of nitrogen in the fermentation of four monosaccharides by 93 members of the genus *Pseudomonas*. When  $\text{NH}_4\text{Cl}$  was used in the basal medium, the maximum number of acid-producing strains was detected. With nutrient broth as the basal medium the number of strains showing positive reactions was dependent upon the incubation period. Thus, with xylose, arabinose, and mannose lengthening the incubation period from two to seven days increased the number of acid-producing strains, but with dextrose the number of acid producers decreased after the longer incubation period. The results with  $\text{NH}_4\text{Cl}$  always showed a slightly higher number of acid-forming strains after seven days than after two days.

In all cases the number of acid-producing strains was much greater in the synthetic medium than in the presence of peptones. Acid production from xylose, arabinose, and mannose was indicated by approximately three times as many strains in the synthetic basal medium as in the peptone-beef extract medium. In the presence of peptones using dextrose as the carbohydrate, the number of acid-producing strains was 67 per cent of the total positive strains indicated in the synthetic medium.

Investigation of the utilization by *Pseudomonas* strains of nineteen carbon compounds showed that with the exception of rhamnose the monosaccharides were decomposed to acids by 93 to 95 per cent of the strains. Sixty to 75 per cent of these bacteria produced acid from the remaining compounds, except glycerol and mannitol, which were fermented, about as readily as the monosaccharides.

An attempt was made to evaluate the potentialities of the organisms as causes of food deterioration on the basis of their proteolytic, lipolytic, and oxidase-producing activities. Of the *Pseudomonas* strains, 57 per cent were proteolytic and 59 per cent were lipolytic, while 41 per cent gave a positive oxidase test. Fifty-three per cent of the *Achromobacter* cultures were lipolytic and 49 per cent produced oxidase, but only 19 per cent had

proteolytic powers. Those organisms constituting the other groups (*Micrococcus*, *Proteus*, *Flavobacterium*, and *Sarcina*) generally showed lesser activities, although 42 per cent of the *Micrococcus* cultures were proteolytic and lipolytic. It is felt that the organisms surviving in chlorinated waters may play a significant role in the spoilage of meats and vegetables stored at low temperatures.

Among the organisms isolated from chlorinated waters, there were groups which might give rise to false positive presumptive tests for coliform organisms through synergistic action. Many of the *Pseudomonas* strains produced acid from lactose, while members of the *Proteus* group produced gas from dextrose, thus fulfilling the conditions necessary for the associative breakdown of lactose with acid and gas production.

The antagonistic action of members of the *Pseudomonas* group against nine coli-aerogenes strains was investigated. In no case on nutrient agar plates, in beef extract lactose broth, or in beef infusion lactose broth, was there any evidence of inhibition of growth or of gas formation by members of the coli-aerogenes group. On agar plates three mixtures of *Pseudomonas* and *Achromobacter* strains showed some inhibitory action. The evidence indicated that the organisms found in the chlorinated waters investigated probably did not interfere with the detection of coliform bacteria, but that, on the basis of specificity of action of inhibitory *Pseudomonas* strains reported by other investigators, upon the first appearance of gas in the presumptive test medium the confirmatory procedures should be rapidly carried through to completion. Retaining 37° C. as the incubation temperature employed for the bacteriological analysis of water would tend to keep this source of error at a minimum since the majority of the *Pseudomonas* species studied did not grow at that temperature. Shipped samples should be refrigerated while in transit in order to prevent the multiplication of *Pseudomonas* types with consequent possible destruction of the coli-aerogenes group present.

# A STUDY ON THE CATALYTIC DECOMPOSITION OF ETHYL ALCOHOL IN THE PRESENCE OF MAGNESIUM OXIDE<sup>1</sup>

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The present investigation traces the influence of magnesium oxide on the decomposition of ethyl alcohol under the following conditions: high and atmospheric pressures, low-space velocity, and the lower temperatures at which decomposition takes place. The experiments were conveniently divided into two series: the decomposition of ethyl alcohol at atmospheric pressure, and the decomposition of ethyl alcohol at high pressure. In the first series of experiments which were conducted under atmospheric pressure, it is difficult to estimate the influence of the walls of the catalyst tube on the decomposition of alcohol. Consequently blank experiments were run to determine the effect of glass. The results showed that the liquid product obtained in the experiments conducted at temperatures from 480° to 602°C. was predominately alcohol. Some acetaldehyde was formed at the higher temperatures. In some of the experiments conducted at temperatures from 365° to 457°C. in which magnesium oxide was used, the liquid product resulting from the decomposition was immediately fractionated. A representative idea of the fractions obtained may be drawn from an experiment in which 400 ml. (312 grams) of alcohol were passed at the rate of 20 ml. per hour through 23 grams of magnesium oxide at 455°C. The liquid product (340 ml., 287 g.) yielded the following fractions: (1) 30-56°C., 7 ml.; (2) 56-65°C., 7 ml.; (3) 65-72°C., 17 ml.; (4) 72-74°C., 7 ml.; (5) 74-77°C., 8 ml.; (6) 77-80°C., 187 ml.; (7) 80-90°C., 45 ml.; (8) 90-116°C., 27 ml.; (9) 116-118°C., 10 ml.; (10) 118-124°C., 2 ml.; (11) residue 22 ml. In this experiment there were also obtained 20 ml. of material which condensed in the dry ice trap and 43.2 liters of gas at 25° C. which analyzed as follows: 2.8 per cent carbon dioxide, 11.1 per cent unsaturated hydrocarbons, 2 per cent carbon monoxide, and 81.5 per cent hydrogen. The identification of individual substances in these fractions was extremely difficult; however, the fractions were classified according to their solubility in the following solvents: water, ether, 5-per cent sodium hydroxide, 5-per cent hydrochloric acid, 5-per cent sodium bicarbonate, cold concentrated sulfuric acid, and 85-per cent phosphoric acid. They were further classified with the following reagents: Tollen's reagent, 5-per cent bromine in carbon tetrachloride, 2-per cent permanganate, and Fuchsin-aldehyde reagent.

The individual experiments showed that from 45 to 55 per cent of the original alcohol was decomposed. However, upon fractional distillation of the liquid product, little information could be obtained as to the composition of the different fractions, because of incomplete separation and the small volume of some of the fractions. Therefore, more liquid product

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was prepared in as nearly an identical manner as possible and fractionated. The corresponding fractions were combined and refractionated. This second fractionation gave a better separation and made it possible to identify several compounds formed in the decomposition. The fractions with the largest volumes obtained from this second fractionation were collected at the following temperatures: (1) below 58°C., (2) 68-75°C., (3) 75-80°C., (4) 86-92°C., (5) 98-103°C., (6) 103-118°C., (7) greater than 118°C.

From these fractions the following substances were identified: acetaldehyde, n-butyraldehyde, methyl n-propyl ketone, n-butyl alcohol, and undecomposed alcohol. Other substances, seemingly present but not identified, were unsaturated in nature.

In some experiments the liquid product obtained from the decomposition instead of being directly distilled was extracted with water. The top oil layer was washed several times with water, dried over anhydrous calcium chloride, and this material fractionated. The following fractions were obtained: (1) 60-61°C., (2) 92°C., (3) greater than 92°C. From these fractions additional information pointed to the presence of unsaturated hydrocarbons.

The water extracted portion was saturated with sodium carbonate and the oxygen-containing compounds separated out, dried over sodium carbonate, and fractionated. From approximately 273 ml. of solution the following fractions were obtained: (1) up to 65°C., 5 ml.; (2) 65-69°C., 6 ml.; (3) 73-76°C., 10 ml.; (4) 77-79°C., 141 ml.; (5) 80-83°C., 9 ml.; (6) 86-90°C., 10 ml.; (7) 90-92°C., 53 ml.; (8) 94-100°C., 48 ml.; (9) greater than 100°C., 10 ml. The same procedure was followed in several other experiments, and the corresponding fractions mixed together and refractionated. The only additional compound identified in these fractions was acetone.

The material contained in the dry ice trap was predominately 1, 3-butadiene containing small amounts of acetaldehyde.

In the second series of experiments which were conducted under high pressure, the decomposition of ethyl alcohol in the presence of a contact agent and the decomposition of ethyl alcohol without a contact agent were studied in a Parr hydrogenation bomb. In the experiments in which the contact agent was used, the 5 grams of magnesium oxide were either intimately ground with 100 ml. of alcohol or added separately along the sides of the cylinder. At stated intervals during the heating period and after the temperature became constant, pressure readings were taken and a curve was constructed to show the course of decomposition. To obtain these curves the pressures developed during the period of heating were plotted as ordinates against time, in minutes, as abscissae. These curves not only delineate the course of the reaction but give some idea as to its rate. When a comparison is made between the increase in pressure that results when a catalyst is introduced into the reaction with that when a catalyst is omitted, some idea concerning the accelerating action of the catalyst can be obtained.

When 100 ml. of alcohol were heated in the high pressure apparatus to different temperatures without a catalyst, a slight decomposition of alcohol occurred at 394°C. However, it was noticed that under the influence of magnesium oxide at the same temperature a more energetic decomposition occurred, as evidenced by the larger volume of gas.

Other experiments conducted at temperatures from 446° to 497°C. using magnesium oxide as a contact agent, indicated that the quantity of liquid products obtained depended upon the temperature of decomposition. In some experiments there was a separation into two layers (a brown upper layer and a colorless lower layer); in other experiments, particularly those conducted at lower temperatures, a single brown-colored liquid was obtained. This liquid, however, on being treated with water, separated into two layers, an insoluble brown layer and a colorless layer, which upon salting out with sodium sulfate separated into two layers. The upper layer was distilled. In the other experiments where the decomposition was slight, only a colorless liquid remained in the container.

For example when 100 ml. of alcohol were decomposed at 446°C. in the presence of 5 grams of magnesium oxide, there were obtained, on the average, 51 ml. of liquid product, separating into two layers, the clear lower layer averaging 17.5 ml. (15.8 grams), and the upper layer 32.5 ml. Shaking of the upper layer with water removed the water soluble products, reducing the volume on an average of 6 ml. Upon fractional distillation, the insoluble portion remaining showed that it did not consist entirely of hydrocarbons, because a carbon-hydrogen analysis did not total above 80 per cent, a result which indicated the presence of oxygen. Traces of acetaldehyde and the presence of unsaturated compounds were also observed in all fractions up to a b.p. of 90°C. The brownish oily liquid with a b.p. greater than 90°C. was probably a mixture of saturated and unsaturated hydrocarbons as shown by a carbon and hydrogen analysis.

The lower colorless layer was subjected to a fractional distillation. A separation and an analysis of these products were extremely difficult because of the small range of boiling points, the similarity of properties or the formation of mixtures. However, an idea of the fractions and their respective boiling-point range may be obtained from the following: (1) to 56°C., (2) 56-69°C., (3) 69-76°C., (4) 77-79°C., (5) 81-86°C., (6) 87-90°C., (7) above 90°C. The distillation loss of the product was due partly to the presence of acetaldehyde, which persistently appeared in the fractions up to and including fraction 5.

In this experiment 22.07 liters of gas were collected at a temperature of 24°C. and had the following composition: 13.4 per cent carbon dioxide, 3.2 per cent unsaturated hydrocarbons, 4.3 per cent carbon monoxide, 40.8 per cent hydrogen, 2.8 per cent methane, 28.6 per cent ethane, and 7.0 per cent nitrogen.

Under the conditions of high pressure in a closed system, within the temperature range 440° to 460°C., 60 to 70 per cent of the alcohol decomposed.

## SOME CHARACTERISTICS OF BACTERIA FROM SURFACE WATER SUPPLIES<sup>1</sup>

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The objectives of the work were as follows:

1. To study the characteristics of some Gram-negative short rods isolated from raw and chlorinated water supplies.
2. To evaluate the probable significance of those "slow lactose fermenting" organisms which are Gram-negative, non-sporulating short rods.
3. To ascertain the resistance of members of the coli-dysentery group to chlorine.

Two hundred twenty cultures were received from four cities employing surface water supplies. These cultures included 163 strains from 93 samples of chlorinated waters. After purification by repeated platings on eosine methylene blue agar, 275 strains (including 195 members of the coli-aerogenes group) were obtained from the original 163 cultures.

Intensive studies were carried out with the 195 coli-aerogenes strains. Thirty-five strains came from water samples obtained during the winter (water temperature less than 5° C.) while the remaining 160 cultures were of summer origin (water temperature 12°C. to 22°C.).

Of the 93 water samples 61 (65.6 per cent) were reported to have had a residual chlorine content of at least 0.4 p.p.m., after a contact period of a few minutes to 6 hours, including 17 samples with a contact period of more than 4 hours, and 12 samples of at least 6 hours exposure. Evidently, then, since coli-aerogenes strains were isolated from the foregoing water samples, the presence of 0.2–0.3 p.p.m. residual chlorine after 10 to 20 minutes cannot be relied upon as an index of the probable absence of members of the coli-aerogenes group.

A large proportion of the strains isolated during the summer fermented lactose broth very slowly at 37° C. (less than 10 per cent gas in 48 hours), whereas they produced gas quite rapidly at 30° C. The occurrence of these aberrant lactose fermenters was relatively as common among strains allocated to the genus *Escherichia* as among those placed in the genus *Aerobacter*. Many of these aberrant strains produced 10 per cent or more gas in 48 hours at 37°C. in the newer presumptive test media, such as brilliant green bile or formate recinoleate broth.

Since 120 (61.5 per cent) of the 195 strains were slow lactose fermenters, it was concluded that when examining chlorinated waters the practice of disregarding gas production in standard lactose broth if the quantity was less than 5 per cent in 48 hours would result in loss of relatively large numbers of members of the coli-aerogenes group.

On the basis of quantity of gas produced in lactose at 37°C. (in 48 hours) 2 groups were recognized. One group, comprising 107 strains, con-

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sisted of organisms which produced 10 per cent or more gas, while the members of the second group (88 strains) produced no gas or, at best, a bubble of gas. These two groups were referred to as Group I and Group II, respectively. Of the strains isolated from water samples during the summer, 83 (51.9 per cent) were slow lactose fermenters, whereas, in sharp contrast, only 5 (14.3 per cent) of the strains isolated from winter water samples were in this category. It was therefore postulated that strains of Group II represent strains washed in from the soil by spring and summer rains.

Correlations were found to exist between season of isolation of the cultures studied and the following characters; the utilization of uric acid, the production of indol and  $H_2S$ , and gas production in cellobiose, salicin, and glycerol. For example, while 145 (91 per cent) of the strains of summer origin produced gas in cellobiose, only 19 (54 per cent) of the strains isolated during the winter were able to produce gas in that carbohydrate. Glycerol was fermented by only 38 (24 per cent) of the strains of summer origin, while of the winter strains 25 (71 per cent) formed gas in glycerol.

With regard to rate of lactose fermentation, while only 12 to 15 strains, fermented inositol and adonitol, all such strains were in lactose Group I, the rapid lactose fermenters. The fermentation of glycerol and dulcitol and the utilization of uric acid were of more frequent occurrence among rapid lactose fermenters (lactose Group I) than among the slow lactose fermenters.

The sanitary significance of the slow lactose fermenters was not definitely established. If they are to be considered significant and if it is desired to include them in the colon index, their detection might be facilitated either by lowering the temperature of incubation for the presumptive test, or substituting some of the newer selective media for the present standard methods lactose broth.

In addition to the 195 members of the coli-aerogenes group, strains of the genus *Proteus* were studied. These *Proteus* strains, when grown in formatericinoleate broth, generally filled the inner tubes with gas while the medium remained perfectly clear, whereas the coli-aerogenes strains generally produced less than 50 per cent gas, and rendered the medium highly turbid.

Among the V.P. negative strains, the utilization of citrate did not correlate well with any other characters. On the other hand, the fermentation of cellobiose correlated highly with 5 of the 10 characters studied, and was therefore used for primary subdivision of the V. P. negative group. For completeness, however, and because citrate has been used so frequently, in the past, a supplementary classification employing citrate as a primary differential character was given in the appendix.

Among the V. P. negative, citrate negative strains there was found a perfect negative correlation between the production of indol and the fermentation of cellobiose and  $\alpha$ -methyl glucoside.

On the basis of a statistical study of the correlation of characters among the 195 coli-aerogenes strains isolated from chlorinated waters, 7

species were recognized as indicated in the following dichotomous key.

Key to the species of the coli-aerogenes strains isolated from the chlorinated waters:

- A. V. P. positive
  - B. Acid and gas produced in glycerol
    - C. Indol positive—(6 strains) *Aero. oxytocom*
    - CC. Indol negative—(7 strains) *Aero. aerogenes*
  - BB. Acid and gas not produced in glycerol—(79 strains) *Aero. cloacae*
- AA. V. P. negative
  - B. Acid and gas produced in cellobiose
    - C. Acid and gas produced in sucrose—(53 strains) *Esch. anidolica*
    - CC. Acid and gas not produced in sucrose—(19 strains) *Esch. intermedium*
  - BB. Acid and gas not produced in cellobiose
    - C. H<sub>2</sub>S positive—(19 strains) *Esch. grunthali*
    - CC. H<sub>2</sub>S negative—(12 strains) *Esch. coli*

Tables were presented showing the distribution of the strains of the species recognized above among the groups suggested by the previous classifications of MacConkey, the American Public Health Association, Malcolm, Stuart *et al.*, and the British Committee.

Observations on the resistance to chlorine were made on 271 strains. Strains of the coli-aerogenes group, which were apparently chlorine resistant, were more frequently encountered during the summer, but considering all of the available data the actual existence of chlorine resistant strains of the coli-aerogenes group was not considered to have been demonstrated.

One strain, however, organism No. 31, was found to be extremely chlorine resistant. It can be differentiated from strains of the coli-aerogenes group but might be confused with them if one were not fairly familiar with the particular organism in question. It conformed to the definition of the coli-aerogenes group as given in Standard Methods of Water Analysis (1936) in that it was a Gram-negative rod for which spores could not be demonstrated, grew aerobically and fermented lactose with gas production. However, the organism differed from those of the coli-aerogenes group in that it failed to grow in brilliant green bile, formate ricinoleate broth, or tryptose-lauryl sulfate lactose broth, and produced very small colonies on eosine methylene blue agar. Further, this organism was also more resistant to heat than were the typical coli-aerogenes strains. However, on prolonged cultivation, both its heat resistance and chlorine resistance were lost. On glucose agar, organism No. 31 produced large transparent, rough (terraced) colonies which had a rubbery texture.

Organism No. 31 resembles strains of *Aerobacillus* in many characters, but differs morphologically and apparently does not form spores.



## BACTERIOLOGICAL STUDIES ON SOME IOWA CREAMERY WATER SUPPLIES<sup>1</sup>

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The types of organisms responsible for protein or fat decomposition in butter suggest that water used in the manufacturing process may be one of the sources of objectionable species. In the usual public health examination, water is studied for the presence of bacteria of intestinal origin that may indicate possible pollution by pathogenic organisms of the same origin. Water not containing these organisms may, however, contain proteolytic and lipolytic bacteria capable of causing serious defects if introduced into butter. Since butter often is stored and transported at temperatures permitting growth of such undesirable organisms, the problem of determining their sources and preventing their entrance into butter is important.

Tests on the water supplies of 70 creameries included examinations for *Escherichia-Aerobacter* species by enrichment in standard lactose broth and in tryptose lauryl-sulfate broth; total bacterial counts on nutrient agar and on tryptone-glucose-extract-milk agar at 37°C.; total, proteolytic, and lipolytic counts on tryptone-glucose-extract-milk agar at 21°C.; examination for *Pseudomonas putrefaciens* by culturing on a special gelatin medium after enrichment in litmus milk at 3°C.; and washing butter granules churned from thoroughly pasteurized cream and testing keeping qualities of the unsalted butter at 21°C.

Examination of 436 unchlorinated water samples from the 70 butter plants indicated that some plant supplies regularly were satisfactory, some regularly were unsatisfactory, while others varied in quality from one examination to another. Certain supplies that would have been considered acceptable from a public health standpoint were not suitable for use in butter manufacture. Over one-half the plant wells regularly gave satisfactory water, but many of these supplies were contaminated in storage tanks. Various city water supplies were unsatisfactory for butter manufacturing purposes.

Coliform organisms regularly were absent from some plant supplies (well and tank), regularly were present in others, and sometimes were present in still others. Of 224 well samples from 64 plants, 132 samples from 38 plants having satisfactory supplies did not contain coliform organisms. Of the 92 samples from 26 plants having unsatisfactory supplies, 54 samples from 22 plants showed coliform organisms; 21 samples showed the organisms only in the 50 ml. portion, 25 in the 50 ml. and 10 ml. portions, and 8 in the 50 ml., 10 ml., and 1 ml. portions. The 54 positive samples included 24 per cent of the 224 well samples, and the 22 plants from which

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they came comprised 34 per cent of the 64 plants represented by the well samples or 85 per cent of the 26 plants having wells considered unsatisfactory.

The 185 tank samples came from 55 creameries. The 28 samples from 9 plants having satisfactory wells and tanks showed no coliform organisms. There were 24 plants which had satisfactory wells but were storing water in unsatisfactory tanks. Of 80 samples from these tanks, 25 showed coliform organisms; 13 showed the organisms in only the 50 ml. portion, 10 in the 50 ml. and 10 ml. portions, and 2 in the 50 ml., 10 ml., and 1 ml. portions. The 25 positive samples included 14 per cent of the 185 tank samples, and the 14 plants from which they came made up 25 per cent of 55 plants represented by the tank samples or 58 per cent of the 24 plants having unsatisfactory tanks but satisfactory wells. Of the 77 tank samples from 22 plants having unsatisfactory wells, 46 samples from 17 plants showed coliform organisms; 21 samples showed the organisms only in the 50 ml. portion, 16 in the 50 ml. and 10 ml. portions, and 9 in the 50 ml., 10 ml., and 1 ml. portions. The 46 positive sample comprised 25 per cent of the 185 tank samples, and the 17 plants from which they came made up 31 per cent of the 55 plants from which tank samples came or 77 per cent of the 22 plants using unsatisfactory wells.

Of the 27 samples from 11 plants using city water (two used only city water), 6 samples from 3 plants, one of which used city water entirely, showed coliform organisms; 5 samples showed the organisms only in the 50 ml. portion, and one in the 50 ml. and 10 ml. portions. The 6 positive samples included 22 per cent of the 27 city water samples.

When experimental butter was washed with water known to contain coliform organisms, the organisms regularly were found in 1 ml. of unsalted butter and usually were found in 0.1 ml.; they sometimes were found in these amounts of salted butter. Commercial butter, from plants using water that commonly contained coliform organisms, regularly contained the organisms when unsalted and sometimes contained them when salted.

As coliform organisms became more numerous in water, total bacterial counts on the water tended to be higher.

The use of tryptose lauryl-sulfate broth on the 436 water samples reduced somewhat the number of spurious presumptive tests, in comparison with the use of standard lactose broth.

The average total bacterial count, after 24 or 48 hours at 37°C., was higher on T.G.E.M. agar than on nutrient agar. The average T.G.E.M. agar count after 48 hours at 37°C. was higher than that after 48 hours at 21°C., but the average T.G.E.M. agar count after 96 hours at 21°C. was the highest count obtained.

Approximately 5 per cent of the water samples yielded *Ps. putrefaciens*; most of the positive samples contained coliform organisms, had total counts (T.G.E.M. agar, 96 hours, 21°C.) in excess of 100 per ml. and produced spoilage in experimental unsalted butter.

Approximately one-fourth of the water samples contained typical

fluorescent organisms; most of the positive samples produced spoilage in experimental unsalted butter.

Some *Pseudomonas* species known to produce undesirable flavors in butter were isolated from certain water samples; these included *Ps. fragi*, *Ps. graveolens*, and *Ps. mephitica*.

While some samples having high bacterial counts did not cause flavor deterioration when used to wash experimental unsalted butter, the tendency was for samples showing high counts to be more generally associated with serious deterioration in butter than samples having low counts.

Addition of 1, 5, or 10 p.p.m. of chlorine to samples of contaminated water, with holding at approximately 10°C. for 15 minutes, resulted in satisfactory destruction of nonsporeforming organisms. Apparently, sporeforming species were not appreciably affected.

## STUDIES ON EDAM CHEESE<sup>1</sup>

FRANK WARNE CREWS

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Until recent years much of the edam cheese sold on the markets of the United States was imported. Domestic demand and curtailment of world trade have increased the manufacture in this country of various foreign cheeses, including edam.

Apparently, there is no definite agreement as to the typical flavor, body, and texture of edam cheese. The cheese is essentially a sweet curd type with the flavor usually varying from a sweet and pleasantly mild, cheddar-like flavor to a slightly acid, cheddar-like flavor. The body and texture range from a dry mealiness to a soft body which is almost pasty, although some of the older reports describe it as a cheese of very firm body that is rather dry, mealy, and very highly salted. Some cheese are free of eyes, while others develop eyes of varying sizes.

The pasteurization of milk for the manufacture of various cheeses presents a problem in flavor development in the finished product. Such treatment of the milk is desirable because of public health reasons and also in order to control objectionable fermentations. However, it appears that enzymes essential to desirable fat hydrolysis and protein decomposition, or organisms responsible for such changes, are destroyed by pasteurization. Apparently, the amounts of lipolysis and proteolysis in various cheeses manufactured from pasteurized milk are limited; as a result the cheese ripens slowly and flavor development is unsatisfactory, with some cheeses showing a tendency to develop a bitter flavor.

An attempt was made to determine the effects of various factors on flavor and body and texture of edam cheese. The factors studied included: (a) pasteurization of the milk; (b) partial skimming of the milk; (c) enzyme materials from various sources added to the milk or curd; and (d) certain bacteria. Size of the cheese, composition of the cheese, time of paraffining, and curing in oil also were considered.

Raw milk cheese commonly developed more flavor than corresponding pasteurized milk cheese cured under the same conditions. More eyes were formed in the raw milk cheese. Acid numbers on the fat of the raw milk cheese were distinctly higher.

Raw, partially skimmed milk cheese developed as much flavor as corresponding raw, whole milk cheese cured under the same conditions. Commonly, the eyes in the former cheese were either more numerous or larger than in the latter cheese. Acid numbers on the fat were higher with the former cheese.

Pasteurized, partially skimmed milk cheese and corresponding pasteurized, whole milk cheese cured under the same conditions were equally lacking in flavor.

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Cheese manufactured from pasteurized, whole milk and pasteurized, partially skimmed milk treated with extract of dessicated mammary tissue tended to develop more desirable flavor than pasteurized, whole milk cheese made without the extract. Usually the flavor depreciated during the second three months of curing, and then there was less difference in flavor between the two types of cheese. Improvement in flavor of the cheese manufactured from treated milk was more noticeable at 55°F. than at 50°F. In most cases the acid numbers on the fat of cheese from treated milk were slightly higher than those on the fat of cheese from untreated milk.

Cheese manufactured from pasteurized, partially skimmed milk treated with extract of frozen mammary tissue tended to develop more flavor than cheese made from untreated milk. Some of the cheese from treated milk showed a slight unclean flavor after three months, and in many instances distinct unclean flavors were present after six months. In general, acid numbers on the fat were slightly higher with cheese from treated milk, but the differences were small.

Cheese manufactured from pasteurized, partially skimmed milk treated with extract of frozen chicken pancreas or with oat flour tended to develop bitter flavors.

Enzyme preparation added to curd did not diffuse to any extent and acted primarily in areas immediately adjacent to the points of addition. At the points of addition the same general effects of the various enzymes were noted as when they were added to the milk, but the flavors were more conspicuous.

A *Micrococcus* culture added to pasteurized, partially skimmed milk tended to produce an unclean flavor in the cheese; when examined after curing six to sixteen weeks, only small numbers of the *Micrococcus* were found in the cheese. Use of *Pseudomonas putrefaciens* tended to give a desirable flavor, although a slight bitterness sometimes was encountered; when examined after curing four to fourteen weeks, the organism was not recovered from the cheese.

In some cases at three months, small cheese (about 600 to 800 grams) showed slightly more flavor development than corresponding large cheese (about 1200 to 1800 grams), but in most instances at six months the flavor criticisms were identical. There was a tendency for eye formation to be less extensive in the small cheese.

Whole milk cheese cured at 55°F. contained from 47.45 to 52.89 per cent fat on the dry basis, while partially skimmed milk cheese had from 34.24 to 45.73 per cent.

The relationships between body and texture and composition of cheese suggest that a weak, soft, or pasty body can be corrected by decreasing either the moisture content or the fat content on the dry basis, while a dry or firm body can be corrected by increasing either the moisture content or the fat content on the dry basis.

In cheese that were paraffined late, the exterior portion of the cheese was considerably higher in both total solids and fat than the interior por-



tion but showed a lower percentage of salt in the cheese and also on the dry basis.

Some lots of cheese made from fat-enriched milk had an unusually fine flavor.

Cheese cured in mineral oil were penetrated by the oil. With the few cheese cured in oil, the body was very soft, and large eyes developed.

Gassy cheese obtained in one of the trials contained relatively large numbers of *Escherichia-Aerobacter* organisms.

# MORDANTING OF WOOL WITH SALTS OF ALUMINUM<sup>1</sup>

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## I. MORDANTING OF WOOL WITH SALTS OF ALUMINUM

A comparison of various salts of aluminum as mordants for wool under different conditions of concentration and pH was made to secure quantitative information about the composition, mechanical behavior, and resistance of the mordanted wool to degradation by acid and alkali. Wool was boiled one hour and 50-volume baths of the basic acetate, chloride, formate, lactate, *p*-phenolsulfonate, sulfate, and tartrate of aluminum and potassium aluminum sulfate and sodium aluminum tartrate, each 0.0025 to 0.0740 g. of  $\text{Al}_2\text{O}_3$  per gram of wool. The aluminum oxide taken up was determined. The results show that wool and aluminum do not combine as a compound. The aluminum taken up by wool from solutions of the tartrate, lactate, and formate of aluminum increased with increasing concentration while that taken up from potassium aluminum sulfate, aluminum sulfate, aluminum *p*-phenolsulfonate, or aluminum chloride attained a maximum and then slightly decreased. The aluminum taken up from a mordanting bath which contained a polyvalent anion was greater than that taken up from a bath which contained a univalent anion.

The amount of aluminum taken up by wool from potassium aluminum sulfate and from aluminum sulfate agreed within experimental error for concentrations between 0.0045 and 0.037 g. of  $\text{Al}_2\text{O}_3$  per gram of wool; however, at a concentration of 0.0740 g. of  $\text{Al}_2\text{O}_3$  per gram of wool, the aluminum oxide of wool mordanted with aluminum sulfate was 0.27 per cent while that mordanted with potassium aluminum sulfate was 1.32 per cent.

The aluminum taken up by wool during 1 hour's boiling in 50-volume baths of aluminum tartrate, potassium aluminum sulfate, and sodium aluminum tartrate at a concentration of 0.0370 g. of  $\text{Al}_2\text{O}_3$  per gram of wool, over a range of pH from 2.5 to 8.2 was studied. The aluminum taken up from solutions of aluminum tartrate, in which the aluminum was present in the anion, increased as the pH decreased from 8.2 to 3.3, as would be expected if wool tended to adsorb negative ions from a solution of low pH. The aluminum taken up from sodium aluminum tartrate was slightly lower than that from aluminum tartrate. The aluminum taken up from solutions of potassium aluminum sulfate, in which aluminum is present as a cation, increased with increasing pH. The maximum aluminum was taken up from this alum at a pH of 3.8 at which point some precipitation of aluminum hydroxide occurred.

A comparison of wool boiled in water 1 hour with wool mordanted in aluminum tartrate, 0.0370 g. of  $\text{Al}_2\text{O}_3$  per gram of wool, showed that this mordanting did not change the total sulfur, sulfate sulfur, or wet strength

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of the wool. The total nitrogen of the wool decreased from  $16.31 \pm 0.05$  to  $16.07 \pm 0.01$  per cent, the change in weight increased from  $-1.0$  to  $+4.2$  per cent, the ash increased from  $0.07$  to  $1.53$  per cent, and the aluminum oxide increased from  $0.00$  to  $1.52$  per cent.

The aluminum taken up by wool from aluminum tartrate,  $0.0370$  g. of  $Al_2O_3$  per gram of wool, was almost completely removed by steeping it in  $0.1518$  *N* sodium hydroxide or  $5.098$  *N* hydrochloric acid for 10 hours at  $40^\circ C$ . A comparison of wool boiled 1 hour in 50 volumes of water and wool mordanted with aluminum tartrate showed that this mordanting neither protected it from degradation nor increased its degradation by either  $0.1518$  *N* sodium hydroxide or  $5.098$  *N* hydrochloric acid in 10 hours at  $40^\circ C$ . as shown by the weight, total nitrogen, total sulfur, sulfate sulfur, and wet strength of the residual wool.

## II. COMPARISON OF THE SULFURIC-ACID AND ALUMINUM-CHLORIDE METHODS FOR QUANTITATIVE ESTIMATION OF WOOL

The aluminum-chloride and the 70 per cent sulfuric-acid methods for quantitative estimation of the wool in cellulosic admixtures have been compared by their effect on the weight, ash, total sulfur, and sulfate sulfur of the residual wool. The change in weight of wool with the aluminum-chloride method varied from  $-2.1$  to  $+1.9$  per cent among 32 determinations; for 5 sets of 6 parallel determinations the means ranged from  $-1.2$  to  $+1.0$  per cent; the sulfate sulfur of the wool was removed and the ash increased from  $0.10 \pm 0.01$  to  $0.43 \pm 0.15$  per cent for one set and to  $1.04 \pm 0.11$  for another set of parallel determinations. The change in weight of wool with the sulfuric-acid method varied from  $-0.6$  to  $+2.4$  per cent among 18 determinations; for 3 sets of 6 parallel determinations the means ranged from  $0.4$  to  $1.4$  per cent; the sulfate sulfur of the wool was increased from its original  $0.30 \pm 0.01$  to  $1.51 \pm 0.08$  per cent, the total sulfur from  $3.76 \pm 0.01$  to  $4.82 \pm 0.07$  for one set, and to  $5.04 \pm 0.15$  for another set of 6 parallel determinations although the ash was lowered from  $0.10 \pm 0.01$  to  $0.05 \pm 0.01$  per cent. With the proportion of wool at a maximum, these data describe the 70 sulfuric-acid method as somewhat the better of the two methods.

# THE MECHANISM OF DRYING OF IDEAL POROUS MATERIALS<sup>1</sup>

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In 1933 McCready and McCabe<sup>2</sup> introduced a method of studying the drying mechanism using heat and mass transfer equations. They assumed that a vaporization plane or zone actually does recede into the drying body, leaving a practically dry region immediately below the surface.

In such a case heat must be conducted through a dry region of the solid as well as the air film at the solid's surface before it can reach the vaporization plane. Likewise, the vapor given off by the body must pass through the pores of the dry region and through the air film before it can escape into the air stream. The method used by McCready and McCabe to study the mechanism of drying was used in this thesis to predict drying rate curves for a cloth slab.

An equation was derived showing the relation between the temperature and the depth of the vaporization plane. The equation accounts for the heat required to vaporize the water present in the body and the heat required to raise the vapor from its vaporization temperature up to the surface temperature of the slab.

If the depth of the vaporization plane is assigned definite values the equation will contain but two unknowns, the temperature of vaporization and the vapor pressure of water corresponding to that temperature. These may be obtained by plotting the equation on the same chart with a vapor pressure curve of water. The intersection of the two curves will occur at the temperature of the vaporization plane and the corresponding vapor pressure of water.

The equation also contains four coefficients; two relating to the air film and two relating to the solid. The film coefficients may be calculated from the known rates of heat and mass transfer in the constant rate period, but the thermal conductivity and the diffusion coefficients can be calculated only when the position of the vaporization plane is known.

Two methods of obtaining the depth of the vaporization plane were used; one depending on temperature measurements made at various depths in the drying body by means of thermocouples and one depending on measurement of electrical resistance.

A series of thermocouples were placed in the slab at various depths. The slab consisted of 160 layers of muslin cloth each 6 inches square. As the vaporization plane recedes into the body it leaves behind it a zone of either complete dryness, or a zone containing no more than the bound water content of the material. In either case the temperature of the zone rises above the vaporization temperature of free water. Therefore, when

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 647.

<sup>2</sup> D. W. McCready and W. L. McCabe. The adiabatic air drying of hygroscopic solids. *Trans. Amer. Inst. Chem. Eng.*, 29, 313 (1933).

the vaporization plane reaches a given thermocouple a rise in temperature is observed. Thus the depth of the vaporization plane may be determined and the thermal conductivity and diffusion coefficients may be calculated at once from the expressions<sup>3</sup>

$$k = \frac{dw}{Ad\theta} \left( \frac{x}{t_s - t_z} \right) \quad (1)$$

$$\text{and} \quad k_g'' = \frac{dw}{Ad\theta} \left( \frac{x}{p_z - p_s} \right) \quad (2)$$

respectively.

Electrodes were also placed in the cloth slab, and the conductivity of each section of the slab was determined. These conductivities were expressed in terms of the number of microamperes that would pass through the wet cloth under an alternating current potential of 4.3 volts. As the vaporization zone recedes into the body, successive layers of cloth become dry. If a dry layer of cloth appears between the two electrodes the conductivity of the section becomes zero and it is evident that the vaporization plane has just passed the electrode placed closest to the surface.

The depth of the vaporization plane as determined by the two methods may or may not be the same, depending on whether the body is hygroscopic. If they are different, vaporization is taking place over a zone. In either case the thermocouple will show only the location of the innermost limit of the region of vaporization since it is the innermost boundary which first intersects the thermocouple and causes a sharp rise in temperature. The upper limit of the vaporization zone is located by means of the conductance measurements, and the difference in the two depths is the thickness of the vaporization zone.

Since the only convenient method of following the course of drying is the determination of the moisture content of the body, a relation between the moisture content of the body and the depth of vaporization plane is needed. The following relation was found to hold in this case.

$$x = R(1 - F/F_a) \quad (3).$$

When Equation 3 is substituted for the depth of the vaporization plane

### <sup>3</sup> Nomenclature

- $k$  = thermal conductivity of the cloth slab.
- $k_g''$  = diffusion coefficient of the vapors through the solid.
- $\frac{dw}{Ad\theta}$  = rate of drying.
- $x$  = depth of the vaporization plane.
- $t_z$  = temperature of vaporization.
- $p_z$  = vapor pressure of water at the temperature  $t_z$ .
- $t_s$  = temperature of the surface of the slab.
- $p_s$  = partial pressure of the water vapor at the surface of the slab.
- $R$  = half thickness of the slab.
- $F$  = the apparent moisture content of the slab.
- $F_a$  = the actual moisture content of the wet zone in the slab.



and values of  $F/F_a$  were taken, the temperature of the vaporization plane could be calculated as well as the rate of vaporization.

The relation between the rate of vaporization and the actual moisture content of the wet zone in the body is of the form

$$\log \frac{dw}{Ad\theta} = aF_a - b \quad (4),$$

where  $a$  and  $b$  are constants. Equation 4 permits the rate of vaporization to be calculated in terms of apparent moisture content instead of the ratio  $F/F_a$ . Then the usual drying rate curve may be drawn as the rate of drying versus the apparent moisture content of the body.

Nine tests were made, of which the last two are typical and are shown in the thesis. Temperatures of  $104.1^\circ$  and  $123.6^\circ\text{C.}$  and humidities of 0.00482 and 0.00694 grams of water per gram of air were used in tests eight and nine respectively. The constant  $a$  in Equation 4 was found to be identical for the two tests, while the constant  $b$  was slightly different. Drying rate curves were calculated for the two tests, and in both cases good agreement was obtained with the observed drying rate curves.

The wet zone in the dry slab of cloth contained free moisture, and that in the vaporization zone averaged about two layers of cloth in thickness.

## EFFECT OF ADDITION OF SALTS ON HYDROGEN OVERVOLTAGE<sup>1</sup>

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Since 1925 considerable research has been done attempting to relate overvoltage to the composition of the solution. However, practically no research has been performed using electrochemically-active metals as electrodes and alkaline solutions as electrolytes. In the present research the effect of the superposition of various concentrations of neutral salts on fixed concentrations of bases was investigated. The electrode material was iron, an electrochemically-active metal.

The method used for making the overvoltage measurements was the "direct" method. Use was made of a two-compartment cell for the anode and cathode, respectively. The compartments were separated by a glass tube filled with surgical cotton to obstruct diffusion from the anode compartment to the cathode. The cathode was connected to a reference cell by a tube filled with the solution in use as an electrolyte. The tube was drawn out to a capillary tip which was pressed against the electrode surface. The solutions were saturated with hydrogen before a run, and throughout the run hydrogen was bubbled into the cathode compartment to stir the solution and thus prevent polarization.

The more concentrated solutions that served as electrolytes were made by adding weighed amounts of the salt to the correct concentration of base. The more dilute solutions were made by appropriate dilutions of the concentrated solutions. The cell was emptied and cleaned for every run. The cathode was also polished before every run.

The electrode was made of a piece of electrolytic iron one side of which had been polished to a smooth surface with No. 00 emery cloth. The other side was soldered to a chromel wire which was sealed into a glass tube filled with mercury for electric connections. The wire and soldered back were covered with a methacrylate plastic coating. The polished face of the iron electrode was 2.25 sq. cm. in area.

The majority of runs were made in the following fashion. The cell was assembled and a preliminary polarizing current of 10 milliamperes was passed for 10 minutes. The current was then shut off, and after 5 minutes the potential was read from the potentiometer. A current of 1/10 milliamperes was then passed, and as soon as feasible the potentiometer reading was taken. The current was increased in steps differing tenfold from the previous step, and each time a reading was taken; a final reading was taken at 150 milliamperes, the limit of the ammeter. The descending series of readings also was taken. At the end of the run the reversible potential was obtained by means of a platinized-platinum electrode.

The runs in 0.02N-, 0.2N-, and 2N-NaOH solutions showed in general

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a decrease in overvoltage from the dilute solutions to the more concentrated. The decrease was most marked between the values for the 0.02N and the 0.2N solution. This decrease was the larger the higher the current density. At the highest densities the overvoltage was the same (within experimental error) for the 0.2N- and the 2N-NaOH solutions.

The effect of  $\text{Na}_2\text{SO}_4$  on overvoltage in NaOH solutions was investigated. In 2N-NaOH solutions added concentrations of  $\text{Na}_2\text{SO}_4$  had little or no effect at the lower current densities (and polarizations), but when the current reached 100 milliamperes there was a depressing effect which was more marked the more  $\text{Na}_2\text{SO}_4$  had been added. In 0.2N-NaOH solutions the results are a little different. For the lowest current density (current equalled 0.1 ma.), there was a consistent increase in overvoltage as the concentration of  $\text{Na}_2\text{SO}_4$  increased. At the other densities, however, there was a maximum in the curve where the concentration of  $\text{Na}_2\text{SO}_4$  equalled the concentration of NaOH. In the 0.02N-NaOH solutions a similar maximum was observed at the point where the concentration of the  $\text{Na}_2\text{SO}_4$  equalled that of the NaOH even at the lowest current density. The values for the 0.2N- and 2N- $\text{Na}_2\text{SO}_4$  solutions were nearly equal.

Data on 2N-NaOH, 2N-KOH, and 0.5N- $\text{Ba}(\text{OH})_2$  were gathered together and presented graphically. The KOH solution had consistently lower values than the NaOH solutions. The  $\text{Ba}(\text{OH})_2$  solution had higher overvoltages at the lower polarizations and lower at the higher than either the NaOH or the KOH solutions.

Solutions 2N in the chlorides of the above metals and 0.2N in the hydroxides were compared. Here again the potassium solutions had lower overvoltages than the sodium solutions, but the barium solutions now had consistently higher values than either the sodium or the potassium solutions.

The data from measurements on 2N-NaCl, 2N- $\text{Na}_2\text{SiO}_3$ , saturated  $\text{Na}_3\text{PO}_4$ , and 0.7N- $\text{NaAlO}_2$  plus 2N- $\text{Na}_2\text{SO}_4$  solutions, all in 2N-NaOH, were also presented and compared with the data on a pure 2N-NaOH solution. Considerable decreases in overvoltage were noted in the case of the  $\text{NaAlO}_2$  and the  $\text{Na}_2\text{SiO}_3$  solutions, whereas increases over the comparison solution were noted in the case of the  $\text{Na}_3\text{PO}_4$  and the NaCl solutions.

An interpretation of the results relative to corrosion was attempted on the basis that the point of zero surface charge lies in the neighborhood of 1.35 volts relative to the saturated calomel electrode. This potential corresponds closely to overvoltages of 0.3-0.4 volt.

Below 1.35 volts, therefore, the  $\zeta$ -potential is positive and above that negative. Hence, at the low polarizations the  $\zeta$ -potential is affected by the negatively charged ions and *vice versa* at the higher polarizations. Particularly in the neighborhood of the zero surface charge,  $\zeta$  is a function of  $\theta$ ; therefore, in that region the equation of Lukovtsev, Levina, and Frumkin,

$$\eta = -\zeta + 2RT/F \ln i - RT/F \ln C_{\text{OH}^-} \quad ,$$

must be used with caution. Also the surface charge (and the  $\zeta$ -potential) varies with changing hydroxide-ion concentration, especially in the least concentrated solutions where the surface is least saturated.

The data gathered in the investigation seemed to show that  $\zeta$  is relatively more affected at a potential of approximately 1.35 volts. Inasmuch as the reversible potential in neutral solutions is about 0.650 volt, the  $\zeta$ -potential must be positive. Hence, this potential will be subject to decrease in the presence of polyvalent negative ions. Therefore, the presence of  $\text{Na}_3\text{PO}_4$  should decrease the  $\zeta$ -potential and increase the overvoltage.

# CHANGES OF STARCH DURING OXIDATION<sup>1</sup>

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Although some two hundred papers have contributed information on the oxidation of starch, only a few of them included studies of the mechanism of the oxidation. The mechanism of one type of oxidation, periodic acid oxidation, has been greatly clarified by Jackson and Hudson (1, 2) and Caldwell and Hixon (3). The success in the study of this reaction depends upon its specificity. In most of the other oxidations of starch the reactions are so involved and the oxidized products so unstable that little progress has been made in the theoretical interpretations.

The present work is intended as a contribution to the mechanism of the halogen oxidation of starch. Two phases of the oxidation of starch by halogens have been studied, viz., the extensive oxidation of starch paste by bromine in neutral solution and the oxidation of raw starch granules by electrolytic sodium hypochlorite.

## I. OXIDATION OF STARCH PASTE BY BROMINE IN NEUTRAL SOLUTION

Earlier analytical studies (4) indicated the general course of the oxidation of starch paste by bromine. Four types of oxidation of the starch molecule were indicated. Confirmatory evidence of each type has since been obtained. Extensive decomposition of the oxidized starch resulted when the usual hydrolytic methods and aqueous methylation procedures were used. In order to stabilize the oxidized starch prior to hydrolysis, methylation was carried out by an anhydrous procedure using methyl iodide and silver oxide on the silver salt of the oxidized starch. There resulted simultaneous methylation of the hydroxyl groups and esterification of the carboxyl groups. The methylated product was hydrolyzed and fractionated. Analysis of the fractions contributed to the confirmatory evidence for the four expected types of oxidation:

1. The oxidation of primary alcoholic groups to uronic acid units produced as much as 50.7 per cent glucuronic anhydride equivalent when measured by evolution of carbon dioxide (5) and somewhat less when measured by furfural production. The presence of glucuronic acid units was confirmed by hydrolysis of the oxidized starch and isolation of glucuronic acid as the cinchonine salt. This was the first isolation of glucuronic acid from a starch product.

2. The oxidation of secondary alcoholic groups to ketone groups was indicated by the reduction of Fehling's solution. Confirmation of the presence of ketone groups was secured by the preparation of an oxime of the oxidized starch. The nitrogen content of the oxime was equivalent to one ketone group in 65 to 75 per cent of the glucose anhydride units.

3. Oxidative production of non-uronic carboxyl groups was indicated

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by the calcium content of the oxidized starch in excess of that calculated to neutralize the uronic acids present. Upon hydrolysis and fractionation there were obtained barium salts of non-uronic dibasic acids of less than six carbon atoms.

4. Indicative evidence for the splitting of hexose units at a glycol grouping was the oxidative decomposition of ketonic-reducing groups in the later stages of oxidation. The instability of the oxidized starch in acid solution is explicable by the presence of mono- or diketo acid units. Such acid units could be further oxidized to dibasic non-uronic acid units. The expected degradation of keto-acid units to non-uronic acid units was likewise confirmed by the separation of barium salts of dibasic acids of less than six carbon atoms.

## II. OXIDATION OF RAW STARCH BY ELECTROLYTIC SODIUM HYPOCHLORITE

An electrolytic process was applied in oxidizing 1-pound samples of raw starch by alkaline sodium hypochlorite. The method is convenient for studying the factors which influence the properties of starch oxidized by chlorine in alkaline solution. Some of the advantages are the purer products and the better recovery in consequence of the ease with which the small amount of salt can be removed.

The feasibility of industrial application of the process is discussed and found to depend upon securing low cost electric power and a suitable anode to replace the platinum used in the laboratory. Graphite anodes were found to be unsatisfactory.

An improved and rapid ferricyanide method for determining the reducing power of starches and dextrins has been developed. In this method the reduced iron is measured directly by a ceric sulfate titration. For starches hydrolyzed by hot or cold acid or oxidized by alkaline hypochlorite, for raw starches and dextrins, the values for reducing power by this method parallel those determined by the longer procedure of Richardson, Higginbotham and Farrow (6). The time for a determination has been shortened from 3 hours to 20 minutes. Many other modified starches, such as the "chlorinated" and "thin-boiling" types, have been measured.

Tables and graphs have been presented to show the various changes which raw cornstarch undergoes during oxidation. These changes were followed by means of rigidity, gel strength, viscosity, turbidity, volume of centrifuged sediment, reducing power, enzymic digestion, and loss of birefringence. Improvements in several of these techniques, especially in the determination of reducing power, enzymic digestion, and loss of birefringence, constitute a portion of the thesis.

On the basis of swelling phenomena microscopically observed and recorded on photomicrographs, from the quantitative determination of birefringence, and from the correlation between viscosity and the volume of the swollen granules, a mechanical theory of the action of the oxidizing agent on starch granules has been presented. This theory agrees with the observed changes in viscosity, rigidity, and gel strength of the oxidized starches.

The chemical mechanism of the bromine oxidation together with the small reducing power and uronic acid content of the "chlorinated" starches affords an explanation of the somewhat localized attack of the oxidizing agent on raw starch granules. The diminished recovery of the starch upon oxidation is due, presumably, to the production of acidic fragments which dissolve in the alkaline medium and are washed out of the oxidized starch product.

The influence of various factors such as heat, alkalinity, anodic current density, and salt concentration on the properties of electrolytically oxidized cornstarch and on the course of the oxidation was studied. Salt concentration and anodic current density had no effect, whereas heat and alkalinity had a marked effect. The upper temperature limit for electrolytic oxidation of cornstarch was between 50 and 55°C. The upper limit of alkalinity was between 0.6 and 0.72 per cent sodium hydroxide.

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# AN INVESTIGATION OF THE CONFIGURATION OF STARCH AND ITS CRYSTALLINE DEGRADATION PRODUCTS<sup>1</sup>

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Knowledge of the configuration of starch has heretofore been largely dependent on chemical methods. In order to obtain definite information regarding the spatial configuration of starch and its degradation products, these have been investigated by X-ray diffraction methods. The unique optical properties of the iodine molecule make it possible to determine the exact orientation of iodine in the crystalline addition products with starch and related substances.

Two crystalline modifications of starch (oriented amylose films and the iodine addition product of V amylose) have given much information regarding the possible configurations of the amylose chain. In addition to these modifications of amylose, the more important low molecular weight crystalline degradation products of starch have been studied.

Maltose is of importance in this study because it is the fundamental unit of the starch chain. The crystalline dextrans discovered by Schardinger (cycloamyloses) form crystalline addition products with iodine which are closely analogous to starch-iodine. Although amyloextrin cannot be obtained in single crystal form, it is of considerable interest since it crystallizes in the same forms as starch.

Maltose hydrate crystals were found to be monoclinic with the following lattice constants:

$$a_0 = 4.9 \text{ \AA.}, \quad b_0 = 15.2 \text{ \AA.}, \quad c_0 = 10.7 \text{ \AA.}, \quad \beta = 82.5^\circ.$$

The unit cell contains two maltose molecules, and it belongs to the space group  $C_2^2-P 2_1$ . The packing dimensions of the maltose molecule are approximately 4.9 Å. (thickness), 7.6 Å. (breadth), and 10.7 Å. (length).

The molecular weights of the Schardinger alpha and beta dextrans were determined by the X-ray method. The crystal data, including number of glucose residues and molecules per cell, are given below:

	$a_0$	$b_0$	$c_0$	$\beta$	vol.	$\rho$	S.G.	$N$	$M$
$\alpha$ ....	15.49	24.06	13.93	—	5195	1.238	$V^4$	24.03	4
$\beta$ ....	15.27	10.24	20.93	68.0°	3034	1.239	$C_2^2$	14.05	2

Alpha dextrin therefore contains six glucose residues per molecule (cyclohexaamylose), and beta dextrin contains seven glucose residues per molecule (cycloheptaamylose). The specific rotations of cyclohexaamylose and cycloheptaamylose are  $[\alpha]_D^{24} = 151.4^\circ$  and  $[\alpha]_D^{24} = 161.9^\circ$ , respectively. Four other crystal modifications of cyclohexaamylose were examined, and the unit cells found are:

<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 696.

modification	$a_0$	$b_0$	$c_0$	S.G.	$M$
1. given above					
2. ....	9.5	38.	14.4	V <sup>4</sup>	4
3. ....	23.4	—	15.9	hex.	6
4. ....	13.9	16.1	24.0	V <sup>4</sup>	4
5. ....	22.0	16.8	8.3	V <sup>3</sup>	2

The ring-shaped cyclohexaamylose molecule is about 8 Å. thick and 13.8 Å. in diameter. In order to satisfy the symmetry requirements of space group V<sup>3</sup> (modification 5), the molecule must have a twofold axis of symmetry. A unique feature of modification 5 is the presence of "tubes" of cyclohexaamylose rings which extend throughout the length of the crystallite.

Cyclohexaamylose combines with iodine and various amounts of iodide to form colored crystalline addition products. Modification 1 ( $C_6H_{10}O_5$ )<sub>6</sub>·I<sub>2</sub>·KI, forms blue-black hexagonal plates or prisms which are extremely dichroic. The unit cell ( $a_0 = 16.00$  Å.,  $c_0 = 39.7$  Å., space-group  $D_6^{4 \text{ or } 5}$ ) contains six cyclohexaamylose molecules in positions of twofold symmetry. Modification 2, [( $C_6H_{10}O_5$ )<sub>6</sub>·I<sub>2</sub>]<sub>2</sub>KI, forms dichroic greenish needles, and modification 3, ( $C_6H_{10}O_5$ )<sub>6</sub>·I<sub>2</sub>, forms orange-yellow needles. Other modifications are formed in the presence of barium ions, etc. In strongly colored modifications 1 and 2, the cyclohexaamylose molecules form long tubelike structures, while the iodine atoms form a linear chain through the center of the tube. This structural feature is responsible for the extreme dichroism of both modification 1 and 2.

Oriented films of amylose are strongly anisotropic. The birefringence is uniaxial, negative. Oriented X-ray diffraction patterns from amylose films confirm previous unit cell determinations for granular (A — B) starches. The 9 Å. dimension of the unit cell corresponds to the length of the fundamental repeating unit in the amylose chain, i. e., maltose. The swelling of amylose films is due to a lateral expansion rather than to a molecular contraction. In amylose films, and therefore in all starches giving A—B patterns, the amylose molecules are in an extended configuration.

Dry amylose in the V (helical) configuration and modification 5 of cyclohexaamylose take up large amounts of iodine vapor, while other starch types remain uncolored. Amylose crystals prepared by butanol crystallization and cyclohexaamylose 5 have similar optical properties before and after taking up iodine, indicating a similarity of structure. Both amylose crystals and cyclohexaamylose modification 5 have tube-shaped structures. In the iodine addition products of these crystals, the iodine molecules enter the tube-shaped structures and are held on the tube axis (helix axis of amylose and molecular axis of cyclohexaamylose). Amylose-iodine gives an X-ray diffraction pattern similar to the V pattern. This pattern may be indexed on the basis of a two-dimensional hexagonal lattice,  $a_0 = 13.63$  Å. A Fourier synthesis of electron density distribution is in agreement with a helical amylose molecule with iodine molecules lying on the helix axis.

B. macerans amylase acts on all starch types except strongly oxidized starch and beta amylase limit dextrin. B. macerans amylase and beta amylase act in the same manner on the starch molecule, i. e., the enzyme works from the nonreducing end of an amylose chain and breaks the chain with the formation of a cycloamylose (or maltose) molecule. Degradation of the amylose chain continues in a similar manner until the action is stopped because:

- (a) the amylose chain is degraded to a low molecular weight stub or to a branch point, or
- (b) the amylose chains are made unavailable to the action of the enzyme by retrogradation or crystallization.

The relative amount of cycloheptaamylose produced may be greatly increased by adding toluene or other precipitants to the digestion mixture.

The specific rotation of amylose is approximately  $[\alpha]_D^{24} = +201^\circ$ . The specific rotation of the cycloamyloses may be calculated by a modification of Freudenberg's equation. The possibility of preparing pure heptaamylose from cycloheptaamylose is discussed.

Acid hydrolysis of the starch granule results ultimately in the degradation of all intercrystalline or amorphous starch, leaving practically intact the original crystallites of the starch granule. Acid hydrolysis of starch pastes tends to increase the ratio of branch linkages to amylose linkages. Acid modification of starch granules tends to eliminate branching, and therefore to make starch more like amylose. The molecular weights of the amyloextrins prepared from different types of granular starches give an indication of the original sizes of the crystallites.



## SEVERAL IMPORTANT INSECT PESTS OF COTTON<sup>1,2</sup>

### I. RELATION OF POPULATION TO MIGRATION II. INSECTICIDAL STUDIES FOR THEIR CONTROL

J. C. GAINES<sup>3</sup>

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Insect pests of cotton, boll weevil (*Anthonomus grandis* Boh.), cotton flea hopper (*Psallus seriatus* Reut.), cotton bollworm (*Heliothis armigera* Hbn.), and thrips (*Frankliniella tritici* Fitch) cause serious losses to the cotton planters of Texas every year. The work herein reported was conducted over a period of years in the Brazos River bottoms near College Station, Texas, in an effort to aid the planters to combat these pests economically.

To determine the periods when the various insects were in flight, a series of tanglefoot traps were installed in both cotton and weed fields. Visits were made to these traps at regular intervals throughout each season to remove and record the number of captured insects. Population records were obtained by making sweeps with a 16" diameter insect net and recording the numbers of insects captured at regular intervals.

The Latin square plat arrangement was used in field plat control experiments, and the data were analyzed by the method of analysis of variance.

#### COTTON FLEA HOPPER

The preferred host plants of the cotton flea hopper are goatweeds and horsemints. Since horsemints mature early and goatweeds late, adult flea hoppers are forced to seek other host plants during the time when neither of these plants is available. In this interim, when horsemints have matured and when there are yet no goatweeds available to the hoppers, cotton is growing rapidly; thus the hoppers are attracted to the cotton, which proves to be an ideal host until goatweeds begin to grow. Adult hoppers, which have developed from nymphs that have been forced to feed on hosts not of their selection or which have developed on horsemint that matured earlier, transfer to cotton. The average date on which this transfer took place was May 10 for the period 1931-36.

Another dispersal period occurred in which adult hoppers transferred from cotton to goatweeds about the time that cotton stopped growing and goatweeds became attractive. The average date of this transfer for the period 1931-36 was June 28, and by August 2 the transfer was practically complete. The population decreased in cotton and had begun to increase in goatweeds.

Maximum temperatures and minimum relative humidity were unimportant factors influencing the dispersal of the cotton flea hopper.

<sup>1</sup> Original thesis submitted December 18, 1937. Doctoral thesis number 453.

<sup>2</sup> Technical contribution 727, Texas Agricultural Experiment Station.

<sup>3</sup> Now with the Division of Entomology, Texas Agricultural Experiment Station.

Rainfall was found to be an important factor influencing the cotton flea hopper population on goatweeds during the fall. In those years when the fall population in goatweeds was high, the spring emergence was likewise high. Apparently the fall population record serves as a good indicator of the number of nymphs which will hatch the following spring.

During April and May of the period 1933-36, nearly four times as many adult hoppers were captured on the highest section of a tall trap as were captured on the lowest section. These higher catches indicate that adult hoppers transfer from distant weed fields to cotton early in the spring.

In the cotton flea hopper control tests, any of the conditioned or unconditioned sulfurs used, ground to either a 200- or 300-mesh fineness, gave from 81.6 to 86.5 per cent kill of nymphs.

#### COTTON BOLLWORM

The growth of the cotton as indicated by plant height and fruit production is a factor which influences the moth population and the number of eggs. Fields of cotton which had stopped growing were no longer attractive to moths for oviposition. These relationships explain the spotted infestations which occur every year. Rainfall during the growing season was also found to be an important factor influencing the growth of cotton and emergence of moths from the soil.

In control tests, the cotton bollworm injury on the check plats was significantly greater than that found on any of the dusted plats. Calcium arsenate, calcium arsenate-sulfur (50-50) using twice the poundage, and calcium arsenate plus 5 per cent Paris green were equally effective in controlling the bollworms, but when calcium arsenate was diluted with 25 per cent lime, thus reducing the poundage of calcium arsenate 25 per cent, the control was decreased. Similar results were indicated by the yields; that is, the yields were significantly lower on the check plats, but they did not differ significantly among the treated plats except that where the calcium arsenate was diluted the yields were lower.

#### MEXICAN COTTON BOLL WEEVIL

In 1930, the field to field movement or general dispersal period began about September 15. On this date, which was much later than the maximum fruiting date of the cotton, a maximum infestation was reached in some fields observed. In others at the same time no infestation existed.

In 1931 the general dispersal period began about September 1, again considerably later than the maximum fruiting date of the cotton. Weevils spread slowly in cotton during the first part of the season until a certain time when they disperse more rapidly, covering a large territory.

The general dispersal period began on the following dates: September 10, 1932; August 27, 1933; September 22, 1934; July 19, 1935; and September 7, 1936. The extent and time of this general dispersal period is not dependent on any one factor, but is influenced by a combination of

such factors as maximum growth of the cotton, infestation or high percentage of squares infested with egg punctures, and climatic conditions.

The trap catches indicated that weevils fly in one direction as freely as in another.

Calcium arsenate alone, calcium arsenate diluted with 25 per cent lime, calcium arsenate plus 5 per cent Paris green, and calcium arsenate-sulfur (50-50) using twice the poundage were equally effective in controlling the weevil. Calcium arsenate diluted with 25 per cent lime controlled moderate infestations of weevils and is recommended to be used on cotton growing in soils which react unfavorably to arsenates.

### THRIPS

All stages of thrips were found in oats, alfalfa, Bermuda grass, and Spanish moss during the winter months. A minimum temperature of 17 degrees decreased the number of thrips but did not entirely kill the population. Such plants as the above named serve as overwintering hosts and furnish ideal places for thrips to develop early in the spring before dispersing to cotton.

Thrips transfer from weeds, oats, alfalfa, etc., to cotton early in the spring. The dates on which the peak of this transfer occurred in the years observed were as follows: May 3, 1933; May 17-24, 1934; May 3, 1935; and April 19-24, 1936.

The population of thrips on cotton increased rapidly after the peak of transfer to cotton occurred.

Rainfall was found to be an important factor influencing the population of thrips on cotton. During the years when little rainfall was recorded in May, thrips increased to very high numbers—281 per plant—while the population did not increase to high numbers—only 10 to 20 per plant—in years when rainfall was normal or above in May.

Planting cotton as remotely as possible from crops which serve as overwintering or early spring hosts will prove a safeguard. Clean and timely cultivation in the spring will promote rapid growth and help young cotton plants to resist thrips injury.

## EQUILIBRIUM IN THE HYDROGEN-METHANE-STEEL SYSTEM<sup>1</sup>

C F GRAY

*From the Department of Chemistry, Iowa State College*

The process of annealing and gas carburizing has emphasized to no small extent the importance of the control of furnace atmospheres. The use of an improper atmosphere in heat treating may be quite serious in some cases where the physical condition and the carbon content of the surface of a steel are important. Most large-scale commercial heat treating is carried out in furnaces heated by fuel gases. Some of the gases to be expected in such an operation would be water, carbon monoxide, carbon dioxide, nitrogen, and possibly some unburnt hydrocarbons of which methane would be the most important. A thorough knowledge of the equilibrium conditions for the various reactions which might occur between these gases and steel is necessary in order to be able to prepare a desirable atmosphere. This investigation was undertaken to obtain equilibrium data for the reaction,



by direct measurement, and to determine equilibrium constants based on the activities of all reactants and products.

A survey of the literature revealed that few direct measurements above the critical range have been attempted, and the results of these measurements for the austenite area are open to question. All previous investigators have presented their data as ratios of the gases present or as equilibrium constants based on only the gases involved. Such an equilibrium constant is sufficient, provided that the solid phases do not vary in composition. This is not the case for the Fe-Fe<sub>3</sub>C system in the austenite area; therefore, the activities of iron and iron carbide which vary with the percentage carbon should be represented in the expression for the equilibrium constant.

A static method of establishing equilibrium was employed. The sample of steel placed in the reaction bulb was large enough (about 400 grams) and the gas sample small enough (about 120 cc. at room conditions) that the carbon content of the steel did not change appreciably for a series of runs. The temperature was automatically controlled within 1 degree Centigrade. The reaction was followed by observing the pressure changes in the reaction bulb. After equilibrium was established the gas sample was withdrawn from the transparent quartz reaction bulb by the expansion into an evacuated chamber.

The hydrogen-methane mixture was analyzed by burning it and collecting the carbon dioxide and water in separate absorption bulbs. The analysis unit was patterned after Pregl's microcarbon-hydrogen

<sup>1</sup> Original thesis submitted May, 1942. Doctor's thesis number 688.

unit. The gas was forced into the analysis unit by allowing mercury to run through a calibrated capillary. All weighing was done on an Ainsworth microbalance.

The metal samples were cut from commercial carbon steel. Each sample was cut in very thin pieces to allow the gas-solid equilibrium to be established more quickly. A commercial grade of hydrogen was purified by chemical means before introducing it into the storage chamber. The methane was obtained from a natural gas well which gave nearly pure methane. This was also purified further by chemical means. Both purified hydrogen and methane were stored over mercury. The hydrogen-methane mixtures used in the reactions were made up from these purified gases.

The pressure of the hydrogen-methane mixture was held slightly above 1 atmosphere. The equilibrium constants were calculated by the equation,

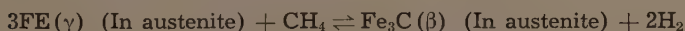
$$K = \frac{N_{\text{Fe}_3\text{C}}}{N_{\text{Fe}}^3} \cdot \frac{N_{\text{H}_2}^2 P}{N_{\text{CH}_4}}$$

where  $N_{\text{Fe}_3\text{C}}$  and  $N_{\text{Fe}}$  are mol fractions in the solid phase,  $N_{\text{H}_2}$  and  $N_{\text{CH}_4}$  are mol fractions in gas phase based on only active gases, and  $P$  is the total hydrogen-methane pressure. After determining the values of  $K$  experimentally, the mol fractions of hydrogen and methane were calculated for one atmosphere by the above equation. The results were as follows:

RUN	STEEL SAMPLE PERCENTAGE CARBON	TEMP. °C.	PERCENTAGE OF CH <sub>4</sub> AT 1 ATM.	PERCENTAGE OF H <sub>2</sub> AT 1 ATM.	K
3.....	0.49	800	1.37	98.63	179
4.....	0.49	800	1.25	98.75	196
5.....	0.49	800	1.18	98.82	208
6.....	0.49	850	.87	99.13	285
7.....	0.49	850	.81	99.19	305
8.....	0.78	850	1.00	99.00	437
9.....	0.78	850	.98	99.02	444
10.....	0.78	800	1.65	98.35	260
11.....	0.78	800	2.17	97.83	196
12.....	0.78	750	2.88	97.12	146
13.....	0.78	750	3.12	96.88	134
14.....	0.78	900	.82	99.18	535
15.....	0.78	900	.69	99.31	633

The results obtained here were compared with those of other investigators.

The heat effect for the reaction,





was calculated to be 23,500 calories at 850 degrees Centigrade from the slope of the straight curve obtained by plotting the log of the equilibrium constant against the reciprocal of the Absolute temperature. A value of 14,700 calories was calculated for the heat effect for the reaction,



at 25 degrees Centigrade. This calculation was based on the above heat effect at 850 degrees Centigrade and heat capacity and transition data for the reactants and products over the temperature interval.

# STUDIES OF SOME FACTORS INFLUENCING COLORATION OF THE GRASSHOPPER, *MELANOPLUS BIVITTATUS* SAY<sup>1</sup>

JAMES McDONALD GRAYSON

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Grasshoppers of the species *Melanoplus bivittatus* Say exhibit two distinct adult color types, with forms which are intermediate between the two. Grasshoppers of both color types and intermediate forms are found in the same locality, having apparently been produced under similar environmental conditions. Mating between grasshoppers of all color types occurs normally. The nymphs show even more variation in color type than do the adults.

The term "light phase" is used to designate the adult grasshoppers that have a distinct yellow coloration on the head, dorsal stripes, sides of thorax, ventral surface of thorax and abdomen, and hind femora. The term "dark phase" is used to designate the adult grasshoppers that have no observable yellow, being gray to bluish or purplish gray on the regions just enumerated. The amount of black pigment in either case is approximately the same and is located on the body as follows: a single stripe on the side and three bars on the top edge of the hind femur, a broad median stripe on the dorsum, and a stripe of irregular outline on the upper edge of either side of the thorax.

In this investigation the principal pigment responsible for the occurrence of the two distinct adult color types was identified, and determinations were made of its intensity in the insect body. A study was made of the effects upon the coloration of the grasshoppers of such factors as temperature, humidity, various colored lights, rearing one per cage versus many per cage, and rearing in darkness. Data were also obtained on the offspring arising in the  $F_1$  generation from mating typical males and females of each color type.

The pigments of the grasshoppers that are soluble in acetone were extracted by a method similar to that used in the extraction of plant pigments. The procedure is described. The water-soluble pigments were extracted by adding hot water to the ground bodies, from which the alimentary canals had been removed. The pigment extract was separated by suction through a coarse filter. No attempt was made to extract the brown and black pigments occurring in the cuticula of the nymphs and adults.

A single yellow pigment is largely responsible for the occurrence of variation in the adult color type. This pigment was identified, by spectroscopic and chemical analyses, as being principally carotin, with occasionally a trace of other pigment of a xanthophyll nature. Carotin was found to be present in a concentration of 0.0436 milligram per gram of body weight in the females; of 0.0397 milligram per gram of body weight

<sup>1</sup> Original thesis submitted July 16, 1941. Doctoral thesis number 646.

in the males (both determinations with the alimentary canals removed); and of 0.266 milligram per gram of tissue in the reproductive organs and surrounding fatty tissue. All determinations were made by comparing the pigment with a 0.2 per cent of potassium dichromate solution in a Bausch and Lomb colorimeter. The identification of the water-soluble pigments was not accomplished. It is suggested that they are perhaps in part chlorophyll decomposition products, and in part certain members of the group known as the flavins.

Descriptions are given of the procedures followed in the rearing of the grasshoppers for the purpose of studying the effects of certain environmental factors on their coloration. Rearing cages of various sizes were used. In some experiments, constant-temperature cabinets were used; in others, approximations were obtained of the temperature and relative humidity either from hygrothermographic records or by making periodical readings of the temperature and determining the relative humidity by means of a sling or hand aspirator psychrometer.

Experiments were conducted to determine the effects upon the coloration of the nymphs, and the color types of the adults of the two-lined grasshopper, of such factors as temperature, humidity, rearing many per cage as opposed to one per cage, the absence of light, and different-colored lights. When reared at low temperatures the nymphs possessed more black pigment than when reared at high temperatures; however, at the higher temperatures there was found to be a tendency toward the production of dark phase adults. The nymphs reared under crowded conditions contained more black pigment than those reared one per cage; however, when reared under solitary conditions there was found to be a tendency toward the production of dark phase adults. No conspicuous differences were detected in the coloration of either the nymphs or the adults of *M. bivittatus* as a result of rearing them through the nymphal period in different humidities, in the absence of light, or under different-colored lights.

Observations were made on the offspring arising from the mating of typical males and females of each color type. The results in the  $F_1$  generation from these preliminary experiments indicated that the color type of the parent may be a factor in the determination of the adult coloration of the offspring.

# FUNGAL AMYLASES AS SACCHARIFYING AGENTS IN THE ETHANOL FERMENTATION OF STARCHY MATERIALS<sup>1</sup>

LU CHENG HAO

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## INTRODUCTION

In order to use starchy materials for alcohol production the starch must be saccharified before being subjected to yeast fermentation. At present barley malt, which is relatively expensive and limited in amount, is used industrially for the saccharification. A substitute for malt which would be cheaper, more easily produced, and give better yields of alcohol is much to be desired.

Certain molds produce considerable quantities of the saccharifying enzyme, amylase. Underkofler, Fulmer, and Schoene (1) developed a method for culturing molds on wheat bran in rotating drums, and found that mold-bran produced higher alcohol yields than did good dried barley malt. During the present investigation a new and more efficient laboratory method for growing molds was employed, the efficiencies of preparations from twenty-seven strains of molds in saccharifying corn mash for alcoholic fermentation was compared, and preliminary studies of the ethanol fermentation of a few other starchy materials were also made.

## METHODS

The bran mash used as medium for growing the molds was prepared by moistening 750 g. of wheat bran with an equal weight of 0.3 N hydrochloric acid. The wet bran was packed into a 3-quart aluminum pot equipped for aeration, and sterilized at 15 lbs. for 30 minutes. The bran was cooled and inoculated with 10 g. of well-sporulated mold culture. After a period of incubation at 30°C. (about 8 hours), the growing mold mass was then aerated for 16 to 24 hours. The mold-bran, which refers to the bran well covered with mold mycelium, was dried and ground, and was used as such for saccharification.

Yields of ethanol from fermentations were employed as the index of the activity of the amylases. Each fermentation mash was prepared by mixing 60 g. of starchy material with 300 ml. of 0.04 N hydrochloric acid, autoclaving at 20 lbs. for 30 minutes, then cooling to conversion temperature and adjusting to pH = 5.0. After saccharification with 3.6 or 4.8 g. of mold-bran, 20 ml. of an active 20-hour culture of yeast (*Saccharomyces cerevisiae*) in 10 per cent beer wort were added. Upon completion of fermentation, alcohol was estimated by distillation and specific gravity determination.

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<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 692.

## RESULTS

Growth of the molds in pots was more rapid and uniform, and the amylolytic activities of the products were greater than when grown in the rotating drum. Saccharification performed at 30°C. for 1 hour gave results as good as saccharification at 55°C. for 1 or more hours. With some molds the yields were consistently higher when saccharification was performed at the lower temperature.

Ethanol yields of at least 90 per cent were obtained with twenty-three of the twenty-seven strains of molds tested. Among eight strains of *Aspergillus*, preparations from *Aspergillus oryzae* No. 2, No. 38, and No. 40 gave highest conversion of starch into ethanol. The average maximum yield of ethanol, using amylase preparations from these molds, was about 93.0 to 93.5 per cent. Amylase preparations produced from *Mucor rouxii* and *Mucor circinelloides* were quite active, while that produced by *Mucor javanicus* was relatively inferior. The amylase preparations produced by species of *Penicillium* were less active in converting starch into alcohol in comparison with the preparations from other genera of molds. Most of the amylase preparations obtained from twelve strains of *Rhizopus* were very active. Amylase preparations from *Rhizopus delemar* No. 12, No. 13, and No. 34, and those from *Rhizopus oryzae* No. 15, No. 32, and No. 33 were particularly good. The alcohol yields from the amylase preparations obtained from the best strains of *Rhizopus* were as good as those obtained from the best strains of *Aspergillus oryzae*. However, preparations from the best strains of *Aspergillus oryzae* seemed to give more consistent results than preparations from any other molds.

Among the different processes tried to reduce the viscosity of the fermentation mash, partial hydrolysis, i. e., use of 0.04 N hydrochloric acid to cook the mash was the best. Premolding, premalting, and thinning cooked mash with mold-bran extract all gave satisfactory results.

Secondary addition of mold-bran gave, in general, an increase of 0.7 to 1.1 per cent alcohol yield. In cases where alcohol yields between 94.5 to 95.0 per cent were obtained without secondary addition of mold-bran, the effect of secondary addition became much less significant.

The addition of traces of ferrous and zinc sulfates to the bran mash increased the amylolytic activity of mold-bran preparations from strains of *Aspergillus oryzae*, while the same salts appeared to retard the effectiveness of the strains of *Rhizopus*. The highest consistent ethanol yields obtained from corn mash saccharified with amylase preparations from *Aspergillus oryzae* grown on bran without addition of mineral salts were about 93.5 per cent, but were 95.0 per cent when the iron and zinc salts were added to the bran.

Preliminary studies of the fermentation of wheat, oats, Spartan barley, Leoti red sorghum, Kafir pink sorghum, and rice saccharified with 6 per cent of five different mold-bran preparations showed that all the various starchy materials tested produced considerable amounts of alcohol. Alcohol yields obtained from fermentations of Kafir pink sorghum and rice were about 95 per cent. Kafir pink sorghum deserves special attention,



because it not only gives high alcohol yields but would also be a cheap raw material for industrial application. Leoti red sorghum and oats gave alcohol yields of about 90 per cent, while wheat and barley generally gave yields below 85 per cent. The cooked mashies of wheat and barley were very thick; it is probable that modifications in liquefaction of the mash, such as premalting or using stronger acid in cooking the mashies, would increase the alcohol yields. Very likely the use of higher concentrations of mold-bran in saccharification would also improve the alcohol yields.

As a conclusion, it can be said that fungal amylases are very satisfactory saccharifying agents in the ethanol fermentation of starchy materials. Besides producing higher alcohol yields than malt, mold-bran is easily prepared and is made from abundant and cheap raw material. It would seem that the use of mold-bran to replace malt in the production of industrial alcohol should hold much promise, particularly in meeting the urgent needs for saccharifying agents in the expanded grain alcohol industry of today.

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1939. Saccharification of starchy grain mashies for alcoholic fermentation industry. Use of mold amylase. *Ind. Eng. Chem.* 34, 734-38.

## A STUDY OF IRON PENTACARBONYL AS A SOLVENT AND REACTION MEDIUM<sup>1</sup>

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Since the discovery of iron pentacarbonyl by Berthelot<sup>2</sup> and Mond<sup>3</sup> in 1891, an interesting body of literature has been published concerning the preparation of this compound, its constitution, properties, derivatives, and uses. However, no work has been done on the study of iron pentacarbonyl as a solvent or reaction medium. Only a few organic solvents are mentioned which will dissolve iron pentacarbonyl, and an investigation has not been made of the possibility of the use of iron pentacarbonyl, since it is a liquid, as a solvent for other substances.

Iron pentacarbonyl as it comes from the manufacturer contains traces of iron enneacarbonyl,  $\text{Fe}_2(\text{CO})_9$ , and other impurities. In order to purify the carbonyl for testing, it is distilled under reduced pressure. Since iron pentacarbonyl decomposes upon exposure to light, the distillation apparatus and receiving flask were painted black, and the distillation was made in a darkened room. Iron pentacarbonyl boils at  $104.6^\circ\text{C}$ ., and the distilling flask was heated in an oil bath at a temperature not to exceed  $120^\circ\text{C}$ . to avoid undue decomposition of the carbonyl.

In conducting the study of iron pentacarbonyl as a solvent, 252 different compounds and elements were used. It was necessary to use anhydrous substances because water is not soluble in iron pentacarbonyl, and any water present affected the solubility. The material to be tested was added to the iron pentacarbonyl in small quantities and the mixture well agitated before further additions were made. If the iron pentacarbonyl remained clear, the substance was considered soluble in the carbonyl. A record was kept of the amount added until the formation of two layers or a cloudiness was observed. This work was done in a darkened room to prevent as much as possible the decomposition of the iron pentacarbonyl due to light.

A liquid substance was considered soluble in iron pentacarbonyl if equal volumes of the two formed a clear mixture and did not separate into layers. Any soluble amount less than the volume of iron pentacarbonyl used was considered as partly soluble. In the case of solid substances, a very small amount was added and the mixture well shaken before further additions were made. The amount added until a cloudiness was produced or until the substance remained undissolved was noted. In some cases, a very evident reaction took place, such as the formation of a gas, a precipitate, or a decided change in color.

A great many liquid organic compounds were found to be soluble in

<sup>1</sup> Original thesis submitted July 29, 1941. Doctoral thesis number 652.

<sup>2</sup> Berthelot, M., *Compt. rend.*, *112*, 1343-49 (1891).

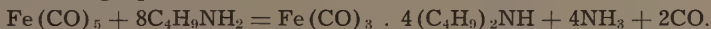
<sup>3</sup> Mond, L., and Quincke, F., *Jour. Chem. Soc.*, *59*, 604-7 (1891).

iron pentacarbonyl, such as, acids, alcohols, esters, ethers, ketones, hydrocarbons, and alkyl halides. However, all compounds of these classes were not soluble but mainly those having low viscosity and low specific gravity. Only two inorganic compounds, arsenic trichloride and phosphorus trichloride, were found to be soluble in iron pentacarbonyl, and both of these compounds are liquids at room temperature. Only a few solid organic compounds were found to be soluble in iron pentacarbonyl and these were sparingly soluble. Benzoic acid, stearic acid, and naphthalene are very slightly soluble and parabromochlorobenzene, the most soluble solid found, dissolves to the extent of 0.5 grams in 5 milliliters.

An effort was made to see if some of the substances which reacted with iron pentacarbonyl, or were insoluble in it, could be dissolved in a liquid which was soluble in the iron pentacarbonyl. The resulting solution was then added to the iron pentacarbonyl and the extent of the solubility of the mixture was observed. Only one such mixture, quinoline in ether, was found to give results which were different. Quinoline alone is not soluble in the carbonyl. Compounds which give a reaction with iron pentacarbonyl were found to give the same reaction when added to the carbonyl in solution in a mutual solvent of the two substances.

Iron pentacarbonyl was found to react with amines and hydrazine to form a blood-red complex compound having a sirupy consistency. The compound formed is unstable and decomposes in the air. It is very difficult to get a good separation of the product from the reacting material. The reaction seems to be of two types, substitution and addition.

The compound formed from the reaction between iron pentacarbonyl and normal butylamine was found to have the composition represented by the formula,  $\text{Fe}(\text{CO})_3 \cdot 4(\text{C}_4\text{H}_9)_2\text{NH}$ . The reaction is accompanied with the evolution of ammonia and carbon monoxide as is indicated by the following equation:



The composition of the compound was obtained by analyzing for the percentages of iron and nitrogen, and the type of amine was determined by means of the reaction with benzenesulfonylchloride. With ethylamine, iron pentacarbonyl forms the unstable addition product represented by the formula,  $\text{Fe}(\text{CO})_5 \cdot 4(\text{C}_2\text{H}_5)_3\text{N}$ . The primary amine being converted to the tertiary amine with the evolution of ammonia. With hydrazine, iron pentacarbonyl forms a mixture containing crystals of semicarbazide and a complex addition compound of the carbonyl and hydrazine.

An effort was made to decompose iron pentacarbonyl by means of oxidizing and reducing agents to give the free element iron. Any oxidizing agents strong enough to decompose the compound also formed a compound of the iron. Free iron was produced only by heating the iron pentacarbonyl to a high temperature. The decomposition taking place best at a temperature around 200°C.

Iron pentacarbonyl was found to have such a low specific electrical conductivity that it can be considered a non-conductor. Solutions of arsenic trichloride, acetic acid, and acetic anhydride in iron pentacar-

bonyl did not have a greater electrical conductivity than the carbonyl alone. Iron pentacarbonyl containing undissolved antimony trichloride or sodium chloride did not show any increase in its electrical conductivity.

Iron pentacarbonyl was found not to react in the vapor state with either metallic aluminum or zinc. There was no deposition of iron on the metals or traces of aluminum or zinc in the condensed iron carbonyl. The vapor of iron pentacarbonyl mixed with air will ignite with a slight explosion at a temperature around  $120^{\circ}\text{C}$ . or above. Oxygen bubbled through iron pentacarbonyl caused spontaneous combustion accompanied by a detonation.

## FLAVOR DEVELOPMENT IN UNSALTED BUTTER<sup>1</sup>

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Unsalted butter for table purposes has increased greatly in commercial importance during recent years. The absence of salt makes it necessary that this type of butter have a high flavor if it is to satisfy consumers. Since diacetyl is the principal compound contributing a desirable flavor and aroma to butter, the amount of diacetyl was used as an indication of flavor development.

The effects of various factors on the content of diacetyl and of its precursor, acetylmethylcarbinol, in ripened cream were studied under laboratory conditions and later under plant conditions. In most trials unsalted butter was manufactured from the ripened cream, and diacetyl and acetylmethylcarbinol contents were determined immediately after churning. Samples of butter also were taken from each churning under plant conditions and were held at different temperatures for various periods before determining the diacetyl and acetylmethylcarbinol and before scoring for flavor.

The diacetyl and acetylmethylcarbinol production in sweet cream, neutralized sour cream, and skim milk generally was greater as the acidity increased during the ripening (range of acidities studied was from 0.25 to 0.55 per cent). Usually the higher the acidity the more effect each unit increase in acidity seemed to have on the production of diacetyl and acetylmethylcarbinol. In a few trials decreases or other trends occurred as the acidity increased.

Addition of 0.05 or 0.10 per cent of citric acid prior to ripening sweet or neutralized sour cream generally resulted in slightly larger yields of diacetyl and acetylmethylcarbinol in the ripened cream. Besides serving as a substrate, the added citric acid caused a slight decrease in pH which tended to favor diacetyl and acetylmethylcarbinol production. This particularly applied when comparative lots of cream were ripened equal periods.

Agitating the cream (sweet or neutralized sour) occasionally during the ripening period resulted in large increases in the yield of diacetyl and acetylmethylcarbinol. In the laboratory, agitation was accomplished by shaking the containers of cream and in the plant by revolving the vat coils. The addition of citric acid to cream before agitating resulted in only slight increases in diacetyl and acetylmethylcarbinol production.

In laboratory trials involving temperature, the yield of diacetyl and acetylmethylcarbinol generally was largest in cream ripened at 50°, next largest at 60°, and lowest at 70°F. In a few trials the production was greater at 60° or at 70° than at 50°F. In nearly all trials the difference

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<sup>1</sup> Original thesis submitted June 3, 1941. Doctoral thesis number 617.



in production of diacetyl and acetylmethylcarbinol among the three temperatures was very small. In trials under plant conditions the temperatures compared were 70° and 62°F. The results were inconclusive as approximately half the comparisons favored each ripening temperature.

Both laboratory and plant trials showed that the production of diacetyl and acetylmethylcarbinol frequently varied in cream ripened with different butter cultures. Occasionally the difference was large.

In laboratory trials increased amounts of butterfat resulted in larger yields of diacetyl and acetylmethylcarbinol. Mineral oil or melted butterfat added to sweet skim milk caused similar results. Sweet cream ripened under atmospheric pressure produced more diacetyl and acetylmethylcarbinol than the same cream ripened under partial vacuum. The difference was greater with an increase in butterfat content of the cream.

There is no advantage in developing large amounts of diacetyl and acetylmethylcarbinol in cream if the corresponding unsalted butter does not retain or develop satisfactory amounts of these compounds before consumption. The retention of diacetyl and acetylmethylcarbinol in fresh butter made from ripened cream varied in both laboratory and plant trials, but in general, large amounts of diacetyl and acetylmethylcarbinol were necessary in the ripened cream for large amounts in the fresh butter. In the trials under plant conditions the unsalted butter was held at 36° to 40°F. for 1 week, and the correlation between the diacetyl and acetylmethylcarbinol contents of the ripened cream and of the butter after holding seemed to be much closer than was true of the fresh butter.

Diacetyl content of unsalted butter held 1 week at 36° to 40°F. increased in 83.9 per cent of the trials and the acetylmethylcarbinol content increased in 67.8 per cent of the same trials. Diacetyl contents in 75.0 per cent of the trials were larger in the samples of butter held 3 days at 60°F. plus 4 days at 36° to 40°F. than in the same samples held 1 week at 36° to 40°F. The acetylmethylcarbinol contents in 72.7 per cent of the trials were larger at the end of the higher holding temperature. Diacetyl contents in 90.7 per cent of the trials increased in butter held 1 month at 36° to 40°F.; only 65.9 per cent of the acetylmethylcarbinol contents increased in these trials. Consistent increases in diacetyl and acetylmethylcarbinol during holding of the unsalted butter at the different temperatures were not produced by varying the percentage of acidity in the ripened cream, the addition of 0.05 or 0.10 per cent citric acid before ripening, agitation during ripening, or varying the ripening temperature of the cream.

The pH of the fresh unsalted butter was higher than the corresponding ripened cream in 90.9 per cent of the trials. The decrease in pH of the butter during holding varied according to the temperature and time of holding.

Butter from cream ripened to a higher acidity than the controls frequently scored slightly higher at the completion of the three holding periods: 1 week at 36° to 40°F., 1 month at 36° to 40°F., and 6 months at -10° to 0°F. The addition of 0.05 or 0.10 per cent citric acid to the cream before ripening generally resulted in the butter scoring slightly higher than

controls at the completion of the three holding periods. Butter from cream agitated during ripening occasionally had an oxidized flavor, and consequently the results were variable. The ripening temperatures of the cream did not seem to affect the score of the butter in any of the three holdings. Butter culture employed in ripening the cream affected the score of the butter, but the results varied slightly according to the holding temperature and period.

Most of the unsalted butter held 1 month at 36° to 40°F. decreased from 0.5 to 1.5 points compared to the same butter scored after holding 1 week at 36° to 40°F. Butter held 6 months at —10° to 0°F. usually deteriorated in score from 1.0 to 2.5 points compared to butter held 1 week at 36° to 40°F.

# PREPARATION OF VARIOUS CHOLESTENES, CHOLESTADIENES AND CHOLESTATRIENES<sup>1</sup>

EGBERT WILSON HOLLINGSWORTH

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The preparation of cholestane derivatives unsaturated in rings C and D was desired in order that their properties could be compared with previously known cholestane derivatives unsaturated in rings A and B. Various steroid derivatives unsaturated in rings C and D are known, but all of them, with the exception of two, possess substitution in the 3-position. This substitution limits the reactions desirable for investigations of rings C and D.

Prior to the preparation of cholestane derivatives possessing mono- or di-unsaturation in rings C and D, the structure of "7-dehydrocholestene isomer" was investigated since this compound should possess two double bonds in conjugation either in the 4,6-position or in rings C and D. It was found that no structure other than  $\Delta^{4,6}$ -cholestadiene could account for the reactions of "7-dehydrocholestene isomer." Catalytic hydrogenation of the isomer yielded a mixture of cholestane and coprostane. The action of hydrogen chloride in chloroform on "7-dehydrocholestene isomer" yielded  $\Delta^{3,5}$ -cholestadiene and the molecular compound of *allo*- and *epi-*allo**-cholesterol. On oxidation with chromic acid a cholestenedione was obtained which on Wolff-Kishner reduction yielded  $\Delta^4$ -cholestene.

Since "7-dehydrocholestene isomer" was thus found to have the structure of  $\Delta^{4,6}$ -cholestadiene, the constitution of two other previously reported products which would be expected from their methods of preparation to be  $\Delta^{4,6}$ -cholestadiene required investigation. One of these, the 5,6-dibromocholestane-quinoline product, was indicated to be an inseparable mixture of  $\Delta^4$ -cholestene and  $\Delta^{4,6}$ -cholestadiene. The other product, obtained by the Wolff-Kishner reduction of  $\Delta^{4,6}$ -cholestadiene-3-one, was indicated to be a difficultly separable mixture containing  $\Delta^{4,6}$ -cholestadiene.

The most logical approach for the preparation of cholestenes unsaturated in rings C and D seemed to be the dehydration of cholestan-7-ol. Cholestan-7-ol was dehydrated under various conditions with anhydrous copper sulfate in xylene and with activated alumina to yield either mainly  $\Delta^8$ -cholestene or a mixture of  $\Delta^8$ - and  $\Delta^{8(14)}$ -cholestenes.  $\Delta^{8(14)}$ -Cholestene was most conveniently prepared by shaking  $\Delta^8$ -cholestene in ethyl acetate with palladium catalyst and hydrogen.  $\Delta^{14}$ -Cholestene was prepared by the treatment of either  $\Delta^8$ - or  $\Delta^{8(14)}$ -cholestene with hydrogen chloride in chloroform.

The structure of  $\Delta^8$ -cholestene was determined by chromic acid oxidation to yield a cholestenone which on reduction with sodium in alcohol followed by oxidation of the resulting product yielded cholestan-7-one. The cholestenone would be expected, therefore, to be  $\Delta^8$ -cholestan-7-one.

<sup>1</sup> Original thesis submitted August 1, 1941. Doctoral thesis number 654.

The structures of  $\Delta^{8(14)}$ - and  $\Delta^{14}$ -cholestenes were assigned by a comparison of their methods of preparation and their properties with analogous  $\Delta^{8(14)}$ - and  $\Delta^{14}$ -unsaturated derivatives.

Various properties of the  $\Delta^8$ -,  $\Delta^{8(14)}$ - and  $\Delta^{14}$ -cholestenes were compared. The specific rotations of  $\Delta^{8(14)}$ - and  $\Delta^{14}$ -cholestenes agree with the generalization that the  $\Delta^{8(14)}$ -unsaturated steroid derivatives are less dextrorotatory than the corresponding saturated derivatives, whereas  $\Delta^{14}$ -unsaturated derivatives are more dextrorotatory. Normal catalytic hydrogenation of  $\Delta^{14}$ -cholestene was found to yield cholestane, whereas  $\Delta^8$ -cholestene is rearranged to  $\Delta^{8(14)}$ -cholestene and  $\Delta^{8(14)}$ -cholestene remains unchanged.  $\Delta^8$ -,  $\Delta^{8(14)}$ - and  $\Delta^{14}$ -Cholestenes were found by titration to consume about three molar equivalents of bromine and about two molar equivalents of perbenzoic acid.

$\Delta^8$ - and  $\Delta^{8(14)}$ -Cholestenes were dehydrogenated by various methods to yield cholestadienes possessing unsaturation in rings C and D.  $\Delta^{7,9(11)}$ -Cholestadiene was prepared by the action of bromine on  $\Delta^8$ -cholestene. The structure of the  $\Delta^{7,9(11)}$ -cholestadiene was assigned from its method of preparation, its absorption spectrum maximum at 243 m $\mu$ , and its failure to yield a maleic anhydride addition product. Treatment of  $\Delta^8$ -cholestene with perbenzoic acid yielded  $\Delta^{7,14}$ -cholestadiene, the structure of which was assigned from its strong laevorotation, its absorption spectrum maxima at 242 and 250 m $\mu$  and its formation of a maleic anhydride addition product.  $\Delta^{8,14}$ -Cholestadiene was prepared from  $\Delta^{8(14)}$ -cholestene by the action of perbenzoic acid, selenium dioxide, bromine, or chromic acid. The structure of  $\Delta^{8,14}$ -cholestadiene was assigned from its methods of preparation, its absorption spectrum maximum at 245 m $\mu$ , and its failure to yield a maleic anhydride addition product. The  $\Delta^{7,9(11)}$ -,  $\Delta^{7,14}$ -, and  $\Delta^{8,24}$ -cholestadienes were found to consume about three molar equivalents of bromine in chloroform solution and slightly less than two molar equivalents of bromine in methanol solution.

Two cholestatrienes were prepared from convenient intermediate compounds used in the preparation of cholestenes and cholestadienes. Thus the dehydration of  $\Delta^{4,6}$ -cholestadiene-3-ol yielded a product which, assuming no rearrangement occurred, should have the structure of  $\Delta^{2,4,6}$ -cholestatriene. Likewise, the dehydration of  $\Delta^{3,5}$ -cholestadiene-7-ol yielded a triene which would be expected to be  $\Delta^{3,5,7}$ -cholestatriene.

# THE DESIGN AND CONSTRUCTION OF A PHOTOELECTRIC SPECTROPHOTOMETER FOR ANALYTICAL RESEARCH<sup>1</sup>

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Before any newly proposed colorimetric method can be utilized to its full extent, it must be thoroughly investigated so that the effect of interfering ions, variations in pH, temperature, and other factors may be determined exactly. The instrument by which this can be done most accurately, readily, and conveniently is a photoelectric recording spectrophotometer. The only available instrument of this type is the Hardy spectrophotometer, which is built by the General Electric Company. Although the results it gives are above reproach, the complexity of the machine and its consequent high cost put it beyond the reach of most analytical chemists. The present problem was undertaken in an attempt to build a spectrophotometer which would give results of the same order of precision as the Hardy instrument, and yet, being simpler and smaller, would be much less expensive and require less highly trained operators to manipulate it.

The most important and critical part of a spectrophotometer, and the nucleus around which the rest of the instrument is built is the monochromator. In this instrument, the monochromator utilized a small replica diffraction grating ruled on a concave mirror, and arranged in a modified Wadsworth mounting in order to obtain high efficiency. The Wadsworth mounting is novel in that the grating is illuminated with a beam of parallel light. By way of modification, a movable mirror was placed in the path of the radiation emergent from the grating, so that this radiation could be focused upon a fixed exit slit. This eliminated the most notable fault of the original Wadsworth mounting, that of requiring an exit slit which moved along a parabola in order to be illuminated by light of the desired wave length.

With this arrangement, no cams were necessary, and the wave length scale was made linear. The mirrors and slits used were not of precision manufacture, and the machine work was done with ordinary shop tools. Even with these variations from the ideal condition, upon calibration of the monochromator with a helium discharge tube, it was found that the wave length scale was in error by a maximum of 1.0 millimicron. By means of a series of carefully placed light baffles and the screening off of unwanted light at every opportunity, the stray light was reduced to considerably less than the 10 per cent which is considered normal for a single monochromator. The amount of stray light was estimated from the transmittancy data of two calibrated glass filters which were obtained from the Bureau of Standards. These data as obtained from the completed

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<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 695.



instrument were compared with those furnished by the Bureau, and were found to be in reasonably close agreement at all places except the extreme ends of the visible spectrum, where the effect of stray light was greatly magnified due to the reduced output of the light source in the blue, and the decreased photocell sensitivity in the red.

The completed instrument used two vacuum emission type photocells having blue-sensitive surfaces. These were chosen after red-sensitive cells and barrier layer cells were tried. By means of a flickering monochromatic light beam which illuminated the two cells in succession, the effect of variation in light source intensity was eliminated. When using this system, the sample was placed in front of one of the photocells, and the solvent in front of the other or compensating cell. This photocell system required a special amplifier which made use of two double triode vacuum tubes in a double balanced bridge circuit. The amplified photocell output was applied to a calibrated resistor, and the fraction of the resistor used indicated directly the percentage transmittancy of the sample. The amplifier used was constructed after seven others had been built and discarded because of unsuitability in the set-up used, or because of some innate fault in the amplifier. The faults observed were those common to photocell amplifiers and other high gain, high resistance circuits, namely, drift and random variations in the output. These were not entirely eliminated in the final circuit, but were considerably reduced.

A wall type galvanometer was used as a null indicating instrument, and also served to integrate the pulses received from the amplifier due to the flickering beam. The mirror of the galvanometer was illuminated by a coiled filament lamp so arranged that its reflected image was focused on a double elliptical mirror, which further reflected the image into either of two photocells. Thus one of the photocells was illuminated whenever the beam of light was in any but the center position, and this happened only when the measuring amplifier was balanced.

Each of these photocells was joined through a resistor to the grid of a Thyatron gas rectifier. These Thyatrons by means of a novel arrangement controlled the movement of a traveling carriage which held the contact of the measuring resistor and also a recording pen. Since the position of the contact was a measure of the percentage transmittancy of the sample, the position of the pen carried along with it was also a measure of this quantity. The pen bore on a piece of centimeter graph paper, and indicated its position by a line on the paper. This paper was carried on a flat carriage, so connected to the wave length mechanism that a movement of 1.0 cm. of the carriage corresponded to a change of 20 millimicrons in wave length. Thus the motion of the paper carriage past the recorder pen caused the wave length to be recorded, and the position of the pen and its carriage was indicative of the percentage transmittancy, the net effect being a directly recorded graph of wave length against transmittancy.

Since the recorder afforded automatic balancing of the amplifier circuit, the operation of the entire instrument was automatic, requiring only

that the small wheel controlling the wave length setting be turned by hand. This could have been motor driven, but precise control of the speed at which the carriage moves was often advantageous, especially when substances having sharp absorption bands were investigated.

There were some faults remaining in the instrument, but most of them could have been eliminated by the use of better electrical and optical parts. The choice of the cheaper parts was made deliberately, in order to find if the better parts were necessary. It was finally found that in order to obtain precise results, precision optical and electrical parts were necessary. The effect of the cheaper pieces was to give reduced sensitivity, increased drift in the electrical circuit, and to accentuate the effect of small stray currents which leaked through the electrical shielding.

#### SUMMARY

By means of the optical system and the electrical system used in this investigation, it has been found possible to construct a workable recording spectrophotometer. The usefulness and reliability of the instrument would have been greatly increased by the use of the highest grade optical and electrical parts in the construction of the instrument.

# HIGH-MOLECULAR-WEIGHT ALIPHATIC COMPOUNDS OF NITROGEN AND SULFUR<sup>1</sup>

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In continuation of studies concerned with the utilization of animal by-products initiated in these laboratories several years ago, a number of long-chained aliphatic compounds of nitrogen and sulfur has been prepared. The investigation has resulted in the development of techniques for applying a number of reactions of low-molecular-weight aliphatic compounds to their high-molecular-weight homologs and includes an examination of the limitations in the concept of homology as applied to long-chained nitrogen and sulfur compounds.

A large number of carboxylic acid salts and amides of *n*-dodecyl- and *n*-octadecylamine was prepared. In addition to those previously reported by the author,<sup>2</sup> *N*-*n*-octadecylammonium nicotinate (m. p. 78-79°) and *N*-*n*-octadecylnicotinamide (m. p. 91-92°) were described. The amine salts of both aliphatic and aromatic carboxylic acids were well-defined crystalline substances that were readily prepared in excellent yields. These have been suggested as derivatives for the identification of acids and of the long-chained amines. The salts may be readily converted to the corresponding amides which may serve as confirmatory derivatives. The chemical and physical properties of these substances show that the principle of homology may be extended to both the salts and amides of high-molecular-weight. Some of the compounds are suggested as lubricants, as insecticides, and as clarifying agents for turbid waters.

Pyrrole derivatives were prepared by treating mucic acid or suitable 1,4-diketones, such as acetonylacetone or diethyl diacetylsuccinate, with *n*-dodecyl- or *n*-octadecylamine. Among the compounds described were *N*-*n*-octadecylpyrrole (m. p. 74-75°), 1-*n*-octadecyl-2,5-dimethylpyrrole (m. p. 39-40°), 1-*n*-dodecyl-2,5-dimethylpyrrole (b. p. 138-140°/1 mm.,  $d_{25}^{25}$  0.86874,  $n_D^{25}$  1.4760), 1-*n*-octadecyl-2,5-dimethyl-3,4-dicarboethoxypyrrole (m. p. 33-33.5°), 1-*n*-octadecyl-2,5-dimethyl-3,4-dicarboxypyrrole (m. p. 107-108°), 1-*n*-dodecyl-2,5-dimethyl-3,4-dicarboethoxypyrrole (b. p. 240-243°/0.5 mm.,  $d_{20}^{20}$  0.99412,  $n_D^{20}$  1.4905), 1-*n*-dodecyl-2,5-dimethyl-3,4-dicarboxypyrrole (m. p. 96-97°). The reactions of long-chained amines to form pyrrole derivatives are the same as the similar reactions of lower-molecular-weight amines and exemplify the principle of homology. Several of the long-chained pyrrole derivatives were stable compounds.

Experiments directed toward the conversion of *n*-dodecylamine to *n*-dodecanol gave relatively poor yields of the alcohol (27 per cent). The method studied involved the action of nitrous acid on the amine at 0°. Various side reactions took place with the formation of *n*-dodecene-1 and

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 642.

<sup>2</sup> Hunter, *Iowa State Coll. Jour. Sci.*, 15, 223 (1941).

nitrogen-containing material that was not identified. The *n*-dodecene-1 was converted to 1-2-dibromododecane (b. p. 156-158°/6 mm.,  $d_{20}^{20}$  1.2815,  $n_D^{20}$  1.4880), the constants of which have not been previously reported. No isomeric dodecyl alcohols were detected. In view of the limitations involved, the reaction is of questionable value for the preparation of long-chained alcohols from the corresponding amines.

The nitration of lauric acid was accomplished. Very poor yields of nitrated material were obtained, and the principal reaction that took place in the presence of nitric acid was oxidation. Ethyl nitrolaurate was isolated as a yellow liquid (b. p. 150-160/1 mm.,  $d_{20}^{20}$  0.98712,  $n_D^{20}$  1.4452) from the esterified reaction products. The data obtained on the nitrated lauric acid were inconclusive but indicated that the most reasonable interpretation of the reaction would include the formation of  $\alpha$ -nitrolauric acid and subsequent decarboxylation of this unstable molecule to nitro-undecane. When ethyl laurate was subjected to the action of fuming nitric acid, hydrolysis first took place, along with oxidation, and the resulting lauric acid then underwent further oxidation and nitration. Fuming nitric acid gave better yields of nitrated material than did concentrated or dilute acids.

The high-molecular-weight even-chained symmetrical thio ethers from *n*-dodecyl to *n*-octadecyl, inclusive, were prepared. These long-chained sulfur compounds, as well as the corresponding sulfoxides and sulfones, have been described elsewhere by the author.<sup>3</sup> The sulfides, sulfoxides, and sulfones each demonstrated chemical and physical properties which justify the extension of the principle of the homology concept to these substances.

Attempts to prepare long-chained sulfonal-type compounds were unsuccessful. *n*-Dodecylamine did not react with acetone to form a mercaptol. 2,2-Dichloropropane, diethyl dibromomalonate and diethyl  $\alpha$ -bromosuccinate did not give the anticipated products with *n*-dodecyl mercaptides. The reaction of sodium on *n*-dodecyl mercaptan gave *n*-dodecyl sulfide. The halogenated compounds listed here oxidized *n*-dodecyl mercaptan to *n*-dodecyl disulfide. The failure of *n*-dodecyl mercaptan to react as do the shorter-chained homologs must be considered as an example of the limitations in the application of homology to high-molecular-weight substances.

The melting point of *n*-octadecyl mercaptan has been erroneously reported in the literature. The pure compound as prepared in this work melted at 31° and not at 56° as previously given.<sup>4</sup>

The sulfonation of stearonitrile met with only fair success. Concentrated sulfuric acid, a mixture of concentrated sulfuric acid in acetic anhydride, and chlorosulfonic acid alone were incapable of introducing sulfonic acid groups into the molecule. Concentrated sulfuric acid brought about the hydrolysis of the nitrile to stearamide. Fuming sulfuric acid

<sup>3</sup> Hunter, *Iowa State Coll. Jour. Sci.*, **15**, 215 (1941).

<sup>4</sup> Collin, Hilditch, Marsh, and Mcleod, *Jour. Soc. Chem. Ind.*, 52, 272T (1933).

converted the nitrile into water-soluble material, and the reaction was accompanied by considerable oxidation.

Stearic acid was not attacked by sulfonating agents of lower strength than fuming sulfuric acid. At 50° the fuming acid attacked stearic acid with the formation of water-soluble material and dark oxidation products. The barium salt of the monosulfonated stearic acid was isolated and found to be exceedingly soluble in water.



## ORGANOMETALLIC COMPOUNDS OF TITANIUM, ZIRCONIUM, AND LANTHANUM<sup>1</sup>

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In order to extend the usefulness of organometallic compounds as synthetic tools in organic chemistry, it is important that new RM types be synthesized. Comparatively few studies on the organometallic compounds of the transition metals have been reported. A review was made of all methods of preparing organometallic compounds; and then several of the general methods were applied to three typical transition metals, titanium, zirconium, and lanthanum. Although the desired RM derivatives were not obtained, some interesting observations were made on the reactions of the titanium, zirconium, and lanthanum halides with RMgX and RLi compounds.

Titanium metal did not react with diphenylmercury when the two were heated together in a sealed tube. When diphenylmercury was heated with lanthanum metal at 135° for one hundred days, a thermal decomposition of the diphenylmercury took place, but no organolanthanum compound was formed.

Solutions of iodobenzene in ether or in benzene did not react with lanthanum at room temperature.

Zirconium chloride in aqueous solution did not appear to react with either benzenediazonium chloride or aluminum carbide. Likewise, no reaction appeared to take place between the bromomagnesium derivative of acetomesitylene<sup>2</sup> and zirconium tetrachloride in ether-benzene solution. Zirconium tetrachloride ammoniate failed to react with ethynylsodium in liquid ammonia.

Grignard reagents and organolithium compounds reacted readily with titanium and zirconium chlorides, but in no case could organotitanium or zirconium compounds be isolated.

The reactions of titanium tetrachloride or titanium tetraethoxide with *n*-butyllithium in petroleum ether immediately produced black, resinous precipitates. These solid products contained part of the *n*-butyllithium, apparently held in the form of complex compounds; they gave positive color tests with Michler ketone. The titanium was reduced to a di- or trivalent state or possibly to the free metal. As mentioned later, the black color of the precipitates is characteristic of di- and trivalent titanium compounds. Upon hydrolysis of the reaction mixtures, aqueous solutions with the characteristic blue-violet color of trivalent titanium ions were obtained; and when treated with ammonia, the solution precipitated black titanous hydroxide.

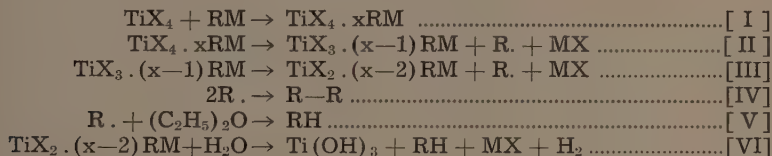
Zirconium tetrachloride reacted slowly with *n*-butyllithium in petro-

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 643.

<sup>2</sup> Fuson, Fugate, and Fisher, *Jour. Am. Chem. Soc.*, 61, 2362 (1939).

leum ether solution, but apparently the zirconium was not reduced. Color tests on the reaction mixture showed that all *n*-butyllithium was removed from solution and appeared in the light brown precipitate. This precipitate, when dry, ignited spontaneously in the air. Apparently a molecular compound of the type  $\text{ZrCl}_4 \cdot 4n\text{-C}_4\text{H}_9\text{Li}$  was formed, and the reaction proceeded no further.

The reactions of  $\text{RLi}$  and  $\text{RMgX}$  compounds with titanium tetrachloride or titanium tetraethoxide in diethyl ether are probably best represented by the following series of equations.



At temperatures below  $0^\circ$ , phenyllithium reacted with titanium tetraethoxide to give a bright orange crystalline product. The orange compound contained phenyllithium as evidenced by its positive color test with Michler ketone;<sup>3</sup> and the titanium was not reduced because upon hydrolysis no trivalent titanium compounds were obtained. The product was probably a molecular compound,  $\text{Ti}(\text{OC}_2\text{H}_5)_4 \cdot x\text{C}_6\text{H}_5\text{Li}$ , as indicated in equation [I]. Upon warming up to room temperature, the orange solid turned black. In accordance with reactions [II], [III], and [IV], biphenyl was formed in yields of from 22 to 54 per cent when phenyllithium or phenylmagnesium bromide was allowed to react with either titanium tetrachloride or titanium tetraethoxide. The reaction of methyllithium with the titanium compounds, however, did not yield ethane, but methane exclusively was produced in yields of about 60 per cent. Similarly, ethylmagnesium bromide reacted with titanium tetrachloride or titanium tetraethoxide to give about 50 per cent yields of ethane exclusively. These simple hydrocarbons were probably formed in accordance with equations [II], [III], and [V], for as Evans and co-workers<sup>4</sup> have shown, aliphatic free radicals are able to abstract hydrogen from diethyl ether and form the simple RH compounds.

It is probable that part of the titanium was reduced to the divalent state in accordance with reaction [III]. This was evidenced by the black color of the reaction products, and this color is typical of divalent titanium compounds.<sup>5</sup> Possibly some reduction to metallic titanium also occurred. Upon hydrolysis, the reaction mixtures evolved hydrogen and RH hydro-

<sup>3</sup> Another proof for the presence of phenyllithium would have been the formation of benzoic acid upon carbonation. However, carbonation of the orange product was not tried.

<sup>4</sup> (a) Evans and Field, *Jour. Am. Chem. Soc.*, 58, 720, 2284 (1936).

(b) Evans and Braithwaite, *ibid.*, 61, 898 (1939).

<sup>5</sup> (c) Evans, Braithwaite, and Field, *ibid.*, 62, 534 (1940).

(a) Georges and Stähler, *Ber.*, 42, 3200 (1909).

(b) Ruff and Neumann, *Z. anorg. allgem. Chem.*, 128, 81 (1923).

(c) Young and Schumb, *Jour. Am. Chem. Soc.*, 52, 4233 (1930).

carbons as indicated in equation [VI]. Divalent titanium compounds are known to react with water and liberate hydrogen.<sup>5</sup> Possibly organotitanium compounds were formed as unstable intermediate products. Equation [II] could have been written in two steps.



Zirconium tetrachloride reacted with RLi and RMgX compounds in much the same way as did titanium tetrachloride; and equations similar to those for titanium tetrachloride ([I] to [VI]) may account for the products. Black resinous precipitates were formed. Upon hydrolysis the black color of the precipitates was discharged; zirconium hydroxide,  $\text{Zr}(\text{OH})_4$ , was formed; and hydrogen was evolved. These properties are characteristic of the black, lower valent zirconium compounds.<sup>6</sup> If organozirconium compounds were formed, they apparently quickly decomposed and could not be isolated. From phenyllithium or phenylmagnesium bromide, biphenyl was obtained in yields of 40 to 56 per cent. Methyllithium reacted with zirconium tetrachloride to give exclusively methane in yields of about 50 per cent; and ethylmagnesium bromide reacted to give exclusively ethane in 50 per cent yields.

Anhydrous lanthanum chloride reacted slowly with phenyllithium to form some biphenyl and black reduction products. The reaction between methyllithium and lanthanum chloride was very slow. A 14 per cent yield of methane was obtained, but most of the methyllithium was bound up with the lanthanum compounds in the form of ether insoluble complexes. No organolanthanum compounds could be isolated from these reactions. No reaction at all appeared to take place between lanthanum chloride and ethylmagnesium bromide.

<sup>6</sup> Young, *Jour. Am. Chem. Soc.*, 53, 2148 (1931).

## A BIOCHEMICAL STUDY ON FLUORINE<sup>1</sup>

- I. Physiological Responses to Fluorine Compounds in the Rat
- II. Attempts to Remove Fluoride to the Non-Toxic Level in Drinking Water

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### PHYSIOLOGICAL RESPONSES TO FLUORINE COMPOUNDS IN THE RAT

The availability of copper and iron as fluoride for hemoglobin regeneration was studied by administering these salts to rats that had first been rendered anemic on a milk diet. Regeneration of hemoglobin in the rats receiving the fluorides was as good as that in the rats that received the same metals in the forms of  $\text{CuSO}_4$  and  $\text{FeCl}_3$ .

The hemoglobin values were unaffected during growth, reproduction, and lactation of rats receiving sodium fluoride at a level of 0.05 per cent in the ration. This was true even though the number of pregnancies were decreased 50 per cent and the lactation was markedly impaired by sodium fluoride at this level in the ration.

Rats were fed sodium fluoride at concentrations of 0.025 and 0.050 per cent in the growing ration, whereas others were fed the two different levels of fluoride in rations to which aluminum sulfate had been added. Growth, reproduction, and the appearance of the incisor teeth of the rats fed fluoride alone and of the rats fed sodium fluoride and aluminum sulfate were compared. The impairment of lactation and of growth, and the damage to incisors by fluoride were overcome to a remarkable extent by feeding aluminum sulfate.

Feeding of aluminum fluoride, cupric fluoride, zinc fluoride, and calcium fluosilicate revealed that aluminum fluoride was markedly less toxic than the other fluorides. Cupric fluoride, which was intermediate in toxicity, caused much more storage of fluorine in the tibiae than did aluminum fluoride.

The toxicity of sodium fluoride, when injected intraperitoneally in lethal quantity, was found to be noticeably decreased by administering aluminum sulfate intraperitoneally. Aluminum fluoride was found to be nontoxic when injected intraperitoneally.

Incorporation of fluoride into tibiae during recalcification was studied by feeding sodium fluoride and cod-liver oil, separately and together, to different groups of rachitic animals. The administration of sodium fluoride along with vitamin D accelerated recalcification as measured by ash determinations and by line-tests. An increase in fluorine content of the bones accompanied the increase in ash content.

The effect of sodium fluoride upon blood sugar levels in the rat was studied by following the changes in blood sugar concentrations in the rat

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after the administration of sodium fluoride alone, sodium fluoride and glucose, and glucose alone to fasted and unfasted rats by means of the stomach tube. Large quantities of sodium fluoride, when administered by stomach tube, caused marked hyperglycemia whether or not glucose was administered simultaneously. The fluoride-induced hyperglycemia was found to be counteracted by insulin in three separate experiments. The feeding of sodium fluoride at 0.10 per cent in the ration of the rat caused markedly lowered blood-sugar levels after a 36-hour fast.

The effects of feeding  $\alpha$ -fluoronaphthalene, *p*-fluorobromobenzene, *p*-fluoriodobenzene, *p*-fluorobenzoic acid, *p,p'*-difluorodiphenyl and fluorobenzene were investigated. Only the first three compounds were found to cause changes in the incisors of the rat.

#### ATTEMPTS TO REMOVE FLUORIDE TO THE NONTOXIC LEVEL IN DRINKING WATER

The removal of fluoride from Ankeny city water was tried using potassium alum at different levels. The removal at two initial pH values was studied for three levels of aluminum sulfate dosage. The change of fluoride content of treated water was determined at different intervals of time of standing in contact with the aluminum sulfate floc. The removal of fluoride from water by the use of commercial aluminum sulfate has been demonstrated with Ankeny city water which resembles a number of waters whose composition has been reported by other investigators.

The amount of fluoride in Ankeny city water was decreased by treatment with both potassium alum and commercial aluminum sulfate in small scale laboratory experiments. Better removal of fluoride with commercial aluminum sulfate was obtained at a pH of 6.95 than at a pH of 7.88. This was true with dosages of aluminum sulfate of 38.7, 19.35, and 11.47 grains per gallon. There was not a linear relationship between the aluminum sulfate dosage and the fluoride removed; the efficiency decreased with increased size of dosage of the aluminum salt.

The time of standing of the water in contact with the floc was found to be a factor in removal. Removal was most rapid during the first two hours of treatment, during which time the floc had settled almost completely.

Removal of fluoride with aluminum sulfate was studied by using a pilot plant that was designed for continuous treatment. This plant consisted of three mixing tanks, a settling tank, and a sand and gravel filter. In the pilot plant experiments commercial aluminum sulfate, C. P. aluminum sulfate, and C. P. aluminum chloride were employed for removal of fluorine. These substances gave similar results. With all three aluminum salts the efficiency of removal was found to vary with the pH of the effluent. The removal of fluoride to the level of 0.65 part per million was accomplished by the use of 15 grains per gallon of aluminum sulfate if hydrochloric acid was added in the first mixing tank and base was added in the second mixing tank in sufficient quantity to return the pH to 7.5. Ten grains per gallon of alum were found to remove fluorine to the level of 1.0 part per million when employed in the same manner.

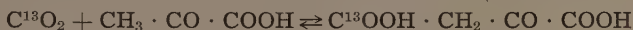


# THE FIXATION OF CARBON DIOXIDE IN OXALACETIC ACID AND ITS RELATIONSHIP TO BACTERIAL RESPIRATION<sup>1</sup>

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The validity of the Wood and Werkman reaction, i. e., the carboxylation of pyruvic acid to oxalacetic acid, has been demonstrated with an enzyme preparation obtained from *Micrococcus lysodeikticus* and with the stable isotope of carbon, C<sup>13</sup>. The reaction is:



Wood and Werkman (1938) have proposed this reaction to account for the utilization of carbon dioxide by heterotrophic organisms.

The enzyme preparation obtained from *M. lysodeikticus* decarboxylates oxalacetate to pyruvate and carbon dioxide very rapidly. The demonstration of the reversibility of the decarboxylation reaction by direct measurement cannot be made owing to the unfavorable equilibrium of the reaction. The dynamic nature of equilibria permits the demonstration of the reversibility of the enzymatic decarboxylation of oxalacetate with the aid of C<sup>13</sup>O<sub>2</sub>. When the decarboxylation is performed in the presence of C<sup>13</sup>O<sub>2</sub>, and permitted to continue until one-half of the original oxalacetate remains, the residual oxalacetate will contain C<sup>13</sup> in the carboxyl group adjacent to the methylene group. This exchange occurs during the enzymatic decarboxylation, but no appreciable exchange occurs during the spontaneous decarboxylation of the acid. The rate at which the equilibrium is attained may not be a factor since the enzymatic and spontaneous reactions were permitted to continue until the same amount of decarboxylation had occurred. The enzymatic reaction may involve components which cannot as yet be identified. In all probability the reactants and the product of this reaction form substrate—enzyme and product—enzyme complexes which yield conditions unlike those in the absence of the enzyme, and therefore produce new equilibrium conditions.

Yeast carboxylase requires magnesium ions and diphosphothiamine for the decarboxylation of pyruvate to acetaldehyde and carbon dioxide. The oxalacetate decarboxylase, however, requires only magnesium or manganese ions.

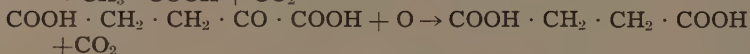
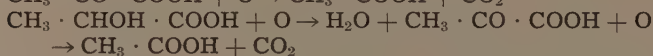
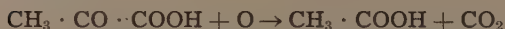
Exchange reactions performed with a magnesium deficient preparation in the presence of oxalacetate and C<sup>13</sup>O<sub>2</sub> gave small exchange values; however the same preparation with added magnesium ions gave exchange values comparable to the "sufficient" preparation.

When fumaric acid is oxidized by the enzyme preparation, quantities of oxalacetate accumulate, which suggests that this oxalacetate has properties unlike those of synthesized oxalacetate. The latter is com-

<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 685.

pletely decarboxylated to pyruvate and carbon dioxide; consequently, it is probable that the physiological oxalacetate is capable of maintaining an equilibrium with its products of decarboxylation. Exchange values obtained with this oxalacetate were substantially higher than those of the synthesized acid. Evidence is presented to show that phosphate may be required for the carboxylation reaction.

To determine whether exchange occurs generally in enzymatic decarboxylations, the following reactions were carried out in the presence of  $C^{13}O_2$ :



No evidence of exchange with  $C^{13}O_2$  was obtained in any of the above reactions. These results emphasize the importance of the Wood and Werkman reaction as the mechanism for carbon dioxide utilization by heterotrophic organisms.

The role of the  $C_4$  dicarboxylic acids in mammalian tissue respiration has been adequately explained by the Szent-Györgyi scheme of hydrogen transport and the Krebs cycle of pyruvate dissimilation. Evidence is present that these acids may have a similar function in bacterial respiration.

WOOD, H. G., AND C. H. WERKMAN

1938. The utilization of  $CO_2$  by the propionic acid bacteria. *Biochem. Jour.* 32:1262-71.

# THE PHOTOCHEMISTRY OF THE FORMATION OF SULFURYL CHLORIDE<sup>1</sup>

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Previous investigations have shown that the dark reaction of sulfur dioxide and chlorine will not take place to any appreciable extent in the absence of a catalyst. The catalyst which is usually used is carbon or camphor. If the reaction is carried out in the presence of carbon at a temperature of about  $-50^{\circ}\text{C}$ ., at which temperature both materials are liquid, there is a rapid conversion to sulfuryl chloride.

The two gases, sulfur dioxide and chlorine, will react in the presence of light to give various products, depending upon the frequency of the absorbed light. The light which is absorbed by the sulfuryl chloride, if it is present as a constituent in the mixture (sulfuryl chloride has a maximum absorption below 2,500 Å), causes decomposition of the molecule into sulfur dioxide and chlorine with possibly some other products in small amounts. Light with a wave length of about 3,000 Å is absorbed by the sulfur dioxide, and a slight decomposition of this gas is observed when light of this wave length is absorbed by the system. Chlorine shows an absorption maximum at about 3,300 Å; a mixture of sulfur dioxide and chlorine reacts to form sulfuryl chloride when the chlorine molecules are the only absorbers of radiation in the mixture. These observed facts were recorded by LeBlanc, Andrich, and Kangro, *Z. Elektrochem.* 25, 229-51 (1919).

The photochemical reaction between sulfur dioxide and chlorine was carried out at  $70^{\circ}\text{C}$ . in a pyrex reaction chamber which was 108.4 cm. in length and 4.8 cm. internal diameter. The windows were thin pyrex plates which were fused on the ends of the reaction tube. The chamber was painted black to exclude light other than the beam which was used for excitation. The gases were circulated in the reaction chamber by an all-glass pump, which consisted of a glass piston (soft iron core sealed inside a pyrex tube) moving alternately in the fields of two solenoids.

A General Electric high-pressure quartz capillary mercury arc (type H6) was used as a source of radiation for the excitation of the chlorine molecules. This arc was enclosed in a pyrex water jacket and cooled by forcing water through this jacket at the rate of about 6 quarts per minute. The light was rendered approximately parallel by a cylindrical glass lens with a focal length of 24 mm.

Sulfur dioxide was prepared by the action of sulfuric acid on sodium sulfite. The gas was passed through water and dried over calcium chloride. It was fractionated at least six times with liquid air, saving the middle portion each time, and the final product was sealed into a storage trap which could be sealed directly to the reaction chamber.

<sup>1</sup>Original thesis submitted May, 1942. Doctor's thesis number 686.

Heating cupric chloride which had been dried at  $110^{\circ}\text{C}.$  for at least 4 hours was found to be the most efficient way of obtaining chlorine gas free of any moisture. The dry powder was heated under vacuum to about  $400^{\circ}\text{C}.$ , and the chlorine gas was liquefied into one of a series of traps by the use of liquid air. The chlorine was fractionated at least six times and the final product sealed into a storage trap. The storage traps were designed so that they could be sealed to an entrance tube leading to the reaction chamber without allowing the gas to come in contact with the air. After the reaction system was evacuated the gases were admitted to the reaction chamber by breaking small glass tips leading from the storage trap to the system. This prevented any contact of the gases with air, moisture, or stopcock grease.

The extent of the reaction was followed by the change in the pressure of the system. There was a decrease in the pressure as the sulfur dioxide combined with the chlorine to form one molecule of sulfuryl chloride. Because of the catalytic influence of many substances on the reaction and the action of the gases on mercury, the ordinary methods of pressure measurement could not be used. A combination manometer and click gage was found to be the most satisfactory. The pressure was measured by a manometer, but the gases in the reaction system were separated from the manometer by a thin glass diaphragm.

The reaction was carried out at  $70^{\circ}\text{C}.$  with the starting pressure of the two gases varying from a pressure of 12 cm. Hg. to a pressure of 60 cm. Hg. The partial pressures of the two gases in the starting mixture were also varied. Curves are given showing the change of the pressure of the system with time. The experimental data indicate that the reaction is first order with respect to the chlorine. In most of the reactions a stationary state was not reached for at least 120 hours.

The quantum efficiency of the reaction of sulfur dioxide and chlorine when activated by light of 4,358 Å was determined by the use of a linear thermopile. The thermopile was calibrated against a standard lamp obtained from the Electrical Testing Laboratories. A glass filter (Corning No. 7) was used to give approximately monochromatic light of this wave length. The quantum efficiency was found to be  $1.2 \pm 0.2$ .

In most of the photochemical reactions in which chlorine absorbs the radiation, it is necessary to postulate the dissociation of the chlorine molecule into atoms in order to explain the high quantum yields which are found. The quantum yield of unity for this reaction would indicate that it is possible for the excited chlorine molecule to combine directly with a molecule of sulfur dioxide to form sulfuryl chloride. The mean life of the excited halogen molecule under the conditions of this experiment is about  $10^{-8}$  seconds, and the time between collisions would be about  $10^{-10}$  seconds.

The degree of dissociation of sulfuryl chloride in the presence of animal charcoal was determined by measuring the density of the partially dissociated gas at temperatures between  $70^{\circ}\text{C}.$  and  $100^{\circ}\text{C}.$  The equilibrium constant ( $K_p$ ) was calculated from the degree of dissociation,

and the  $\Delta H$  of the reaction was found from values of  $K_p$  at different temperatures. The value of  $\Delta C_p$  has been given by Arii, *Bull. Inst. Phys. Chem. Research* (Tokyo) **10**, 256-65 (1931) as:

$$\Delta C_p = -1.1 + 8.0 \times 10^{-3}T - 1.86 \times 10^{-5}T^2$$

and  $\Delta H_0$  was determined as 12,795 calories from the data given above.

The integration constant from the free energy equation was found to be  $-42.26$ . This gives an equation for the calculation of the free energy at any temperature:

$$\Delta F = 12,795 + 2.53T \log T - 2.0 \times 10^{-3}T^2 + .31 \times 10^{-6}T^3 - 42.26T.$$

The free energy of the dissociation of sulfuryl chloride was determined by statistical methods by the use of Raman data for the molecule, and these values were found to agree favorably with the experimental values.



## GENETIC AND MORPHOLOGIC CHARACTERS AFFECTING THE POPPING EXPANSION OF POPCORN<sup>1</sup>

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Popping expansion, or popping volume, measured by the units of volume of popped corn obtained from an original unit of shelled corn, is used as the primary criterion of quality of popcorn. The importance of this measure to the operators of commercial establishments is obvious, since their product is sold on the basis of volume rather than weight. A high expansion is also associated with palatability because the larger, lighter, and fluffier kernels are usually the more tender.

Except for evidence obtained from studies to improve the popping expansion by mass selection, little is known of the inheritance of popping quality, although it is reasonable to assume that the expansion of popcorn is conditioned by certain properties of the endosperm and pericarp, and hence the mode of inheritance may be very complex. This investigation was devoted to a study of the relation between the popping expansion of inbred lines and their hybrids, the relation of certain kernel characters and popping expansion, and other factors concerning the development and evaluation of inbred lines.

Twenty-nine inbreds classified from previous work as high or low in popping expansion were selected from the varieties of Yellow Pearl and Japanese Hulless. The high expansion inbreds ranged from 25.4 to 31.1 volumes and the low expansion inbreds from 15.0 to 23.4 volumes. Two hundred two crosses between these inbred lines within and between the two groups of varieties were studied. The popping expansion of an inbred line was found to give a fairly reliable index of its general performance in hybrid combinations. Crosses of high expansion inbreds tended to give high expansion hybrid combinations, and hybrids involving low expansion inbreds tended to be low. Crosses of high  $\times$  low expansion inbreds tended to be intermediate in expansion. The mean of a group of hybrids was found to approach the mean of the parental inbreds. Although these results were generally obtained, consistent differences in crosses were shown for certain inbreds having approximately the same volume, and hence it should be recognized that not all high expansion inbreds transmit this character to their progeny.

Intertype hybrids between Yellow Pearl and Japanese Hulless seemed to offer much promise particularly for home use, since these crosses tended to combine the yield of the Yellow Pearl with the tenderness of the Japanese Hulless. These crosses perhaps would not be suitable for certain commercial uses such as "Karmel corn" or where good keeping quality is necessary in the popped corn.

<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 683.

The effect of xenia on popping expansion was found to be very slight and not of sufficient magnitude to constitute a serious source of error in comparative yield trials.

Data on the effectiveness of selection for popping expansion within an open-pollinated variety indicated that the open-pollinated progenies of high expansion ears were superior to those with low expansion.

An attempt was made to evaluate the relative importance of general and specific combining ability for popping expansion. General combining was found to be of greater importance in the early evaluation of inbred lines.

The weight, length, and width of seeds, yield, and number of unpopped kernels were found to be negatively correlated with popping expansion while thickness and density of seeds exhibited slight positive correlations with expansion.

# EXTRACTION OF OIL FROM SOYBEANS USING A MIXTURE OF TRICHLOROETHYLENE AND ETHYL ALCOHOL AS A SOLVENT<sup>1</sup>

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In order to eliminate the danger of explosions in solvent soybean extractant a mixture of ethyl alcohol and trichloroethylene, was developed. process which can be operated by nontechnical men in soybean producing regions, a continuous process for extracting oil from soybeans, using as extractant a mixture of ethyl alcohol and trichloroethylene, was developed.

The use of a mixture of ethyl alcohol and trichloroethylene has a number of advantages. If the mixture contains appreciable quantities of alcohol, it will be less expensive than pure trichloroethylene or other nonexplosive solvents suitable for small extraction plants. Ethyl alcohol, while inflammable, is not nearly as dangerous as gasoline, and in mixtures with trichloroethylene, it is quite safe.

A study of the solubility of soybean oil in mixtures of ethanol and trichloroethylene revealed that while pure ethanol will dissolve only approximately 12 per cent of soybean oil at 60°C., a mixture of ethanol and trichloroethylene containing approximately 10 per cent trichloroethylene by weight, will dissolve soybean oil in all proportions above 60°C. Small quantities of water in this mixture decrease the solubility of the soybean oil greatly; however, the addition of more trichloroethylene compensates for the decrease in solubility. If the proper concentrations are used, a hot mixture of trichloroethylene and ethanol, after extracting the oil from soybeans will, on cooling, separate into two phases. The upper phase will contain relatively small quantities of oil while the lower phase will usually contain over 50 per cent oil. The upper phase, because of its low oil content, can be used without evaporation to extract more oil. The lower phase can be treated in a stripping apparatus to remove the solvent, leaving the oil.

In the extraction process developed, the means for contacting the beans and solvent, called the extractor, consisted of a 6-ft. section of jacketed 2-in. standard iron pipe, closed at one end. This pipe was set at a slight angle from the horizontal and was fitted at the lower end (which was closed) with two short upright 2-in. standard iron pipes attached at 2 in. and 8 in. from the lower end, respectively. Bean flakes were introduced into the upright pipe farther from the lower end with a short feed screw from a hopper and were allowed to fall to the bottom through the solvent. A screw conveyor, contained in the extractor, then moved the beans through the solvent to the opposite end of the extractor. The solvent, moving countercurrent to the beans, was taken off through the other upright pipe.

Attached to the upper end of the extractor by means of a tee fitting

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<sup>1</sup> Original thesis submitted June 25, 1941. Doctoral thesis number 639.

was the drier consisting of a 6-ft. length of jacketed 2-in. standard pipe placed in such a position that its center line coincided exactly with the center line of the extractor. The screw conveyor of the extractor was extended through this pipe and the beans emerging from the solvent in the extractor were moved directly into the drier. Steam in the jacket of the drier caused the solvent in the beans to evaporate. Between these two sections of pipe and attached by means of the tee fitting was a condenser. The solvent evaporating in the drier was moved to the condenser by a stream of air flowing countercurrent to the beans and the condensed vapors were returned to the extractor washing the effluent beans. The noncondensable gases from the condenser were vented through unextracted bean flakes in the feed hopper which absorbed residual quantities of solvent vapors. The extracted beans passed through the drier and were discharged intermittently through an *Everlasting* valve.

The lixivium leaving the extractor was first passed through bag filters to remove fine material and was then cooled and allowed to settle in a settling tank. The upper layer was continuously siphoned off and was allowed to flow into the casing of a bucket pump from which it was introduced into the extractor approximately 3 feet from the lower end. The lower layer was stripped in a stripper of special design consisting of a number of horizontal steam pipes placed one underneath the other, and over which the impure oil cascaded and fell into a heated trough underneath. The pipes and trough were all contained in a sheet metal jacket to prevent loss of solvent. In order to keep the vapor pressure of the trichloroethylene in the jacket as low as possible, cooling plates, or condensers, consisting of flat hollow plates, through which cooling water was circulating, were suspended near the steam pipes. The solvent evaporating from the oil condensed on these plates, collected in the bottom of the jacket and was discharged through an opening in the bottom into the casing of the bucket pump.

Numerous runs, many over 24 hours in duration, proved that the oil content of the beans could be lowered to approximately 1 per cent if bean flakes less than 0.020 inches thick were used and if the extraction time was approximately 20 minutes. The solvent composition found most satisfactory was that of about 25 per cent by weight of trichloroethylene having a specific gravity of 0.910. Hot water at 70°C. was passed through the jacket of the extractor. The higher the temperature, the better the extraction; however, at a temperature of 73°C. the solvent began to boil. The moisture content of the solvent would not increase if the beans contained less than 6 per cent moisture and provided the drier steam pressure was kept approximately 10 lb. per sq. in. The solvent became dehydrated when dry beans were used. Solvent losses less than 1 per cent of the weight of beans processed were observed. The capacity of the extraction process was approximately 1 lb. of beans per hour. The ratio of solvent to beans in the extractor found most satisfactory was 1400 ml. per lb. of beans. If a solvent velocity of approximately 1.5 ft. per hour and a solvent specific gravity of 0.910 were used, practically no fine mate-

rial would appear in the lixivium. The oil obtained was of good quality and had properties similar to oil obtained from the expeller process.

A number of control analyses were devised. The oil in the meal was determined by stirring a sample of beans with trichloroethylene and determining the oil content of the solution with sensitive hydrometers which were calibrated for changes in temperature. The residual quantities of trichloroethylene in the finished oil were determined by steam distilling the trichloroethylene from a sample of impure oil, condensing the steam and trichloroethylene and measuring the quantity of trichloroethylene in the distillate making corrections for the solubility of trichloroethylene the water.

The trichloroethylene in impure oil was also determined colorimetrically with the Fujiwara reaction in which a definite quantity of impure oil was added to a boiled mixture of pyridine and 10 per cent sodium hydroxide solution, giving a red coloration which was compared to standards prepared at the same time.

The relationships between the vapor pressure, temperature and composition of mixtures of trichloroethylene and soybean oil, and mixtures of trichloroethylene, soybean oil, and alcohol were studied. In the first mixture, the vapor pressure at a definite temperature is directly proportional to the per cent by weight of solvent. A similar relationship held for the second mixture; however, this second relationship was only approximately linear.

The absorptive power which soybean flakes have for solvent vapors in mixtures with air was investigated. Trichloroethylene can be absorbed from air with unextracted soybean flakes. The rate of absorption is directly proportional to the difference between the vapor pressure of the trichloroethylene above the oil in the soybean flakes and the vapor pressure of the trichloroethylene in the air. This is a useful property of soybean flakes since vent gases can be passed through a column of fresh in-coming bean flakes scrubbing out residual quantities of vapors. The beans pass directly into the solvent and return the solvent to the system. This property can also be used in connection with stripping operations. Air, or other gases, can be used to strip the solvent from oil and after condensing as much of the solvent as possible, the remaining gases can be scrubbed out with unextracted bean flakes. By so doing, the use of steam for stripping can be entirely eliminated and the stripping can be done at much lower temperatures producing a better grade of oil.

Studies were made on the effect of various conditions on the rate of extraction of oil from the beans. Temperature, flake thickness, and flake size were found to have much greater effect on the rate of oil extraction than oil in the solvent, moisture in the beans, solvent-bean ratio, and type of agitation. A mixture of trichloroethylene and alcohol, containing approximately 25 per cent trichloroethylene by weight and present in the ratio of 300 ml. of solvent to 100 gm. of beans, was found to extract the oil as rapidly at 60° as trichloroethylene in the cold.



# PART I: BASE EXCHANGE EQUATIONS APPLIED TO IOWA SOILS<sup>1</sup>

## PART II: ACID OXIDATION METHOD FOR DETERMINING SOIL CARBON

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### PART I: BASE EXCHANGE EQUATIONS APPLIED TO IOWA SOILS

A number of equations have been derived which were intended to express the mathematical relations between the exchange capacity of a soil, the amount of base displaced, and the amount of displacing ion added. An equation derived by Vageler and Woltersdorf (3) and a somewhat similar equation derived by Gapon (1) have been found to be satisfactory expressions of the relationships of base exchange in some soils.

The equation developed by Vageler was  $\frac{1}{y} = \frac{1}{S} + \frac{1}{SC} \left( \frac{1}{x} \right)$ , in

which  $y$  was the amount of cation adsorbed per unit weight of soil;  $x$  was the amount of displacing ion added per unit weight of soil;  $S$  was a constant giving the maximum base exchange capacity of the soil, and  $C$  was a constant. When  $y$  was defined as the amount of base liberated per unit weight of soil, then  $S$  became the total exchangeable bases present in the soil. Since the equation represented a straight line only two experiments, producing two sets of values for  $x$  and  $y$ , were needed to fix the line.

Greene (2) pointed out that the supposed constants in Vageler's equation varied with a change in the relative amounts of soil and water but that a ratio of one part soil to five of water was suitable for most soils.

The law of mass action was the basis for the derivation of the equation by Gapon which was

$\frac{1}{\Gamma} = \frac{1}{\Gamma_{\infty}} + \frac{1}{K\Gamma_{\infty}} \left( \frac{C_1}{C_2} \right)$ . The terms  $\Gamma$ ,  $\Gamma_{\infty}$  and

$K$  were identical with the terms  $y$ ,  $S$ , and  $C$  in Vageler's equation, and  $C_1$  and  $C_2$  were the equilibrium concentrations expressed in moles per liter of the displaced and displacing ions, respectively.

Vageler's and Gapon's equations were here tested in order to ascertain their applicability to base exchange in Iowa soils. The effect of varying the soil water ratio on the exchange capacity as calculated by Vageler's equation was also studied on two soils.

In this study  $y$  and  $\Gamma$  were defined as the amount of base liberated per unit weight of soil and  $S$  and  $\Gamma_{\infty}$  as the total exchangeable bases held by the soil in its normal condition. In order to obtain the values for  $y$  and  $\Gamma$ , weighed amounts of air-dry soil were allowed to come to equilibrium with solutions of ammonium acetate of varying, known concentrations.

<sup>1</sup> Original thesis submitted December 17, 1941. Doctoral thesis number 665.

Values for  $C_2$  were obtained by subtracting  $\Gamma$  from the initial amount of ammonium acetate added. All of the soils tested were slightly acid in reaction with pH's ranging from 5 to 6.

Vageler's equation failed to produce straight lines when applied to the data obtained from seven Iowa soils. When values for  $x$  and  $y$  were obtained by varying the amount of soil and displacing ion in a given volume of solution, a smooth curve resulted which gave a calculated value for  $S$  that agreed well with the exchangeable bases obtained by leaching the soil with five 100 ml. portions of 1.0  $N$  ammonium acetate solution. When a second volume of solution was used, a second smooth curve resulted whose slope and change in slope was different from the first, but whose intercept on the  $y$  axis was unchanged. The larger the volume of the solution the more nearly straight was the curve obtained, that is, the more nearly constant was the value of  $C$ .

The exchangeable bases in the soils tested were mostly Ca and Mg.

Therefore, Gapon's equation became 
$$\frac{1}{\Gamma} = \frac{1}{\Gamma} + \frac{1}{K\Gamma_{\infty}} \left( \frac{\sqrt{C_1}}{C_2} \right)$$
 since the

equation for the exchange reaction according to Gapon should be written  $XCa_{1/2} + NH_4^+ \rightleftharpoons 2XNH_4 + \frac{1}{2}CA^{++}$ . This equation produced curved lines when the volume of the solution was held constant and the amount of soil and displacing ion varied. Straight lines were obtained when the same initial concentration of displacing ion was used and the amount of soil varied.

When Vageler's equation was assumed to produce a straight line and two points used to fix the line, the calculated value for  $S$  on a Clarion loam top soil varied with the soil-salt ratio but not with the soil-water ratio. However, a change in the soil-water ratio from 1:2.5 to 1:10 caused the calculated value for  $S$  on Shelby loam to vary from 13.2 to 12.4, but this difference was small compared to that caused by an equivalent change in soil-salt ratio.

Vageler's equation was found superior to Gapon's in expressing exchange between  $H^+$  and  $CA^{++}$  or  $Na^+$ .

The capacity of Clarion loam to hold bases was found to vary markedly with the pH of leaching solutions used to saturate the soil with calcium. The capacity was a linear function of the pH over a range of 2.5 to 7.0.

## PART II: ACID OXIDATION METHOD FOR DETERMINING SOIL CARBON

A wet oxidation method for determining the organic carbon content of soils was developed. The apparatus required no expensive or special pieces and could be assembled in any laboratory. The oxidation was carried out on 0.5 to 2.0 g. of air dry soil in a 50 ml. side arm distilling flask. Two grams of  $K_2Cr_2O_7$  and 25 ml. of a 60:40 solution of concentrated  $H_2SO_4$  and 85 per cent  $H_3PO_4$  were used when one gram samples were analyzed. The  $CO_2$  evolved was absorbed in  $Ba(OH)_2$  in an evacuated flask and the excess base titrated with standard HCl using thymol blue

indicator. The time required to make one complete determination was from 20 to 25 minutes. The results obtained agreed closely with those from the dry combustion method, the difference between the two methods being much less than the probable error due to sampling.

A reservoir was placed between the digestion and absorption flasks to facilitate the manipulation of the apparatus. A 3:1 glycerine-water solution was used as a confining liquid for the  $\text{CO}_2$  in the reservoir in place of mercury. Potassium iodide was added to the glycerine solution in order to remove the  $\text{Cl}_2$  and any  $\text{CrO}_2\text{Cl}_2$  formed when samples containing chlorides were analyzed.

Carbonates were removed from the soil previous to the wet oxidation by boiling the soil for one minute in a solution containing 5 per cent  $\text{H}_2\text{SO}_4$  and 5 per cent  $\text{FeSO}_4$ . This procedure did not cause any measurable loss of organic carbon.

The reaction could be accelerated by the dropwise addition of 3 ml. of 5 per cent  $\text{H}_2\text{O}_2$  to the digestion mixture during the collection of the second half of the gases from the reaction flask.

Amounts of chlorides in excess of 1 per cent chlorine caused the values obtained for organic carbon to be low when the  $\text{Cl}_2$  and  $\text{CrO}_2\text{Cl}_2$  were removed by KI in the glycerine solution.

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## A STUDY OF THE ABSORPTION SPECTRA OF SOME NEODYMIUM COMPOUNDS<sup>1</sup>

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Nearly all of the chemical and physical properties of an atom except those properties depending upon mass are determined by the energy states of the outermost or valence electrons and their behavior in various fields. If these energy states were known for all the atoms in a substance, prediction of its chemical and physical properties should be possible. This idealized goal has by no means been attained but rapid progress is being made in this direction.

A study of the absorption spectra of some neodymium compounds was undertaken in order to make available a greater amount of good experimental data to check future theoretical work. Some examples checking present theory using the data obtained are given.

For the purpose of the research undertaken two salts of neodymium, namely, the hexagonal nonahydrated neodymium bromate and the A form of neodymium oxide, were prepared and analyzed. The spectra of the compounds were photographed over the range from 3800 Å to 8500 Å and at the following four temperatures: room temperature (ca. 300°K), solid carbon dioxide in acetone (ca. 200°K), liquid ethylene (ca. 170°K), and liquid nitrogen (ca. 80°K). The instruments used for photographing the spectra were a Hilger E1 quartz Littrow spectograph, a 14,448 line Wadsworth mounted three-meter grating spectograph, and a twenty-one-foot Pashen mounted grating spectograph. Conglomerate spectra of both the bromate and the oxide were obtained and measured and, in the case of the bromate, single crystal spectra were obtained at liquid nitrogen and room temperatures; also, spectra of the bromate single crystals were obtained at liquid nitrogen temperature using polarized light.

The absorption lines, as recorded on the photographic plates, were measured on a micro comparator and were calculated to wave numbers using known iron arc lines as base lines. Tables of the absorption lines of the salts are presented listing the wave lengths of the lines in both Angstrom units and wave numbers. For the bromate, in addition to measurements for conglomerates at both room temperature and liquid nitrogen temperature, visually estimated intensities of the single crystal spectra using polarized light are recorded in tabular form.

Using graphs of wave numbers of absorption lines, plotted on a scale of one millimeter equals one wave number, constant differences in wave numbers were found which showed a temperature dependence as expressed by the Boltzmann relation. The energy levels located by this method for the bromate were 0, 116, and 380 wave numbers and for the oxide 0 and 245 wave numbers above the basic state. Higher levels were

<sup>1</sup> Original thesis submitted December 17, 1941. Doctoral thesis number 664.

also found which do not influence spectroscopic calculations of properties at room temperature; also some evidence was found for intervals of about 20, 30, 40 wave numbers and other such values recurring frequently throughout the spectra. It seems highly probable that these small constant frequency differences arise from vibrational frequencies superimposed on the electronic states. Vibrational frequencies should be a function of the mass of the atoms (a constant) and the force constants. Due to the fact that the 4f electrons are somewhat shielded from the influence of neighboring groups by the completed 5s and 5p shells, the force constants should not be affected much by the electronic states and therefore should not differ much from state to state, so that to a first approximation the superimposed vibrational frequencies would be the same for each electronic level. However, these frequencies should suffer slight modification insofar as the various energy states influence the force constants. Therefore, these intervals should not be exactly constant but should fluctuate around certain values.

A tentative energy diagram was presented for the 16,000 wave number multiplet of the nonahydrated bromate incorporating the results obtained.

Following the method of Penney and Schlapp, the theoretical curve for the variation of magnetic susceptibility of neodymium oxide with temperature was calculated from the spectrographic data. This curve was compared with the experimental points of other workers. The agreement between the experimental points and the calculated curve is very satisfactory up to fairly high temperatures where the higher levels start to come into the calculations.

Specific heats due to electronic vibration were calculated for both salts using an equation as developed by Giauque. Since only the lower electronic level for neodymium oxide was found experimentally from the spectra it was necessary to calculate the higher level by means of the energy level equations of Penney and Schlapp. This level was calculated to occur at 839 wave numbers. Experimental values have not been reported as yet for these salts in order to check the calculated values, but work on this phase is in progress elsewhere.



# THE AVAILABILITY OF CERTAIN FORMS OF ORGANIC PHOSPHORUS TO PLANTS AND THEIR DEPHOSPHORYLATION BY EXO-ENZYME SYSTEMS OF GROWING ROOTS AND BY SOIL CATALYSTS

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Studies were made of the ability of corn and tomato plants to absorb phytin, lecithin, yeast nucleic acid, the mononucleotides of yeast nucleic acid, calcium glycerophosphate, and ammonium hydroxide- and water-soluble organic phosphorus of soil. Prior to the assimilation tests the plants were grown for 30 to 55 days in a complete nutrient solution with a minimum phosphorus concentration. All absorption trials were made with complete nutrient solutions (pH 5.5), using the tested phosphorus carrier as the only source of phosphorus. Absorption was determined by sampling the solutions at 6-hour intervals and analyzing for inorganic and total phosphorus; organic phosphorus was found by difference. A special technique was used to measure any breakdown of the organic compounds by microorganisms. Three crops of corn (one series of tests with each) and one crop of tomatoes (two series of tests) were used in the study; all series were run in duplicate or triplicate for each compound in 2-gallon crocks containing three to four corn plants or seven tomato plants.

The rate of uptake of phytin approached that of  $\text{KH}_2\text{PO}_4$  while the absorption of lecithin was considerably slower and more erratic in repeated tests. As an average of all the tests approximately 47 per cent of the phytin was assimilated in 6 hours and 66 per cent in 12 hours as compared with 56 per cent absorption of  $\text{KH}_2\text{PO}_4$  in 6 hours and 82 per cent in 12 hours. Lecithin was absorbed at the rate of 25 per cent of the total in 6 hours and 33 per cent in 12 hours. Most of the absorption tests were made with an initial concentration of approximately 1.00 p.p.m.  $\text{PO}_4$ . When the concentration was increased to about 5.00 p.p.m.  $\text{PO}_4$ , the rate of absorption of phytin and  $\text{KH}_2\text{PO}_4$  was constant for the two 6-hour intervals; this was not true for the tests made at lower concentrations. Lecithin repeatedly showed a greater rate of absorption during the first 6-hour period than it did during the next 6 hours.

A 1:2 soil-water extract of a heavily manured Webster silt loam contained 0.36 p.p.m.  $\text{PO}_4$  in organic form. Corn plants 30 days old were unable to absorb any of this organic phosphorus in 12 hours, although the same plants were rapidly absorbing the inorganic phosphorus in this extract. Thirty-two to 54 per cent of the organic phosphorus in water extracts of two Gray-Brown Podzols (Dunmore silt loam and Westmoreland silty clay) was mineralized by a hypobromite treatment which had been shown to release 75 per cent of the phosphorus in nucleic acid but had little or no effect on phytin.

<sup>1</sup> Original thesis submitted May, 1942. Doctor's thesis number 684.

Attempts to study direct absorption of calcium glycerophosphate, nucleic acid, mononucleotides, and dilute ammonium hydroxide soluble organic phosphorus from soil were frustrated by a mineralization of the phosphorus in these carriers by "exo-enzyme" systems of the roots of tomato and corn plants. Intact roots of tomato plants which had been grown in soil exhibited the same action when washed and placed in a water solution of calcium glycerophosphate. Phytin, lecithin, and the organic phosphorus in water extracts of the prairie soil were resistant to the root-borne enzymes of corn and tomato plants.

The source of the exo-enzyme systems of roots was definitely shown to be the sloughed-off cellular material coating the roots in solution cultures, which resulted from a release of root cap and epidermal cells to the rhizosphere during normal root development. A microscopic examination of this gelatinous cellular material showed it to be composed largely of well-nucleated, intact cells which underwent considerable swelling and elongation soon after being released from the root proper. There was some evidence of rupture and release of the contents of a few of these cells under the solution culture conditions, but the bulk of the cells appeared to maintain a well-preserved condition for a considerable period after detachment.

The previous level of phosphorus nutrition of corn and tomato plants had no measurable effect on the nuclease activity of their roots. The roots of phosphorus-starved plants exhibited a slightly higher glycerophosphatase activity than those of plants which were given ample phosphorus prior to the tests.

The "extra-root" glycerophosphatase of corn plants had an optimum reaction of pH 4.0 at 27°C. in 12-hour tests. Maximum activity of the same system was obtained at 45°C. (pH 4.0) in 9-hour tests.

Optimum pH for the nuclease system of corn roots, as measured by release of inorganic phosphorus at 27°C. in 12 hours, was about 6.3. Maximum activity of this system was obtained at 60°C. when a pH of 7.0 was maintained for 12 hours.

It was pointed out that this solvent action of root-borne catalysts has a direct bearing on fertility problems and emphasizes the role of the plant in a complex soil-plant system. This was offered as additional evidence of the inadequacy of chemical soil tests alone in determining fertility needs.

Soil (Ames fine sandy loam) was examined to find out whether it possessed catalytic properties similar to roots. After preliminary tests on the effectiveness of toluene as a soil-sterilizing agent, it was used as an antiseptic in these studies of the catalytic properties of soil. Calcium glycerophosphate when incubated at pH 4.0 and 45°C. in toluene-treated soil underwent 66 per cent mineralization in 18 hours from an initial concentration of 210 p.p.m. of organic phosphorus.

Dephosphorylation of nucleic acid by soil catalysts was only about one-third as rapid as the breakdown of calcium glycerophosphate when optimal conditions for the respective systems were maintained.

Optimum reactions (pH 6.3 to 7.0) and temperature (60°C.) for the dephosphorylation of nucleic acid were the same for the activity of root-borne enzymes as for soil catalysts. The similarity in the activity curves of these systems was suggested as evidence that the catalytic properties of soil may have originated in part from residues of plant roots. It was pointed out that the rapid catalytic hydrolysis of some of the organic phosphates would be a major factor in determining the penetration and distribution of these materials when added to soil, and consequently affect any advantage they may have over mineral phosphates as a source of phosphorus.

# BIONOMICS OF IOWA MOSQUITOES<sup>1</sup>

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Investigations of Iowa mosquitoes were prompted by the increased prevalence of certain mosquito-borne diseases in Iowa and the desirability of more complete knowledge of the species which occur within the state. The data presented are based upon 647 larval collections and rearings, 116 collections of adults taken while biting, 31 miscellaneous collections, and 783 trap catches. Collections were made in all counties of the state during the breeding seasons of 1939, 1940, and 1941.

Previous to this study, 15 species of mosquitoes were reported in scientific literature from Iowa. In this investigation 39 species were found to occur within the state. These species may be separated into 8 genera as follows: *Aedes*, 17; *Anopheles*, 4; *Culex*, 6; *Mansonia*, 1; *Orthopodomyia*, 1; *Psorophora*, 6; *Theobaldia*, 3; and *Uranotaenia*, 1.

Several Iowa mosquitoes are important vectors of certain diseases which are known to occur within the state. The increased prevalence of human malaria which occurred in Iowa in 1939 and 1940 was dependent upon *Anopheles quadrimaculatus* Say as the principal vector. Other Iowa species of this genus which may act as vectors are *Anopheles walkeri* Theobald, *Anopheles punctipennis* (Say), and *Anopheles occidentalis* Dyar and Knab. At least 5 Iowa mosquitoes are known to be able to transmit the virus of equine encephalomyelitis. During the period from 1937 to 1941 losses to Iowa farmers and stockmen due to this disease may be conservatively placed at \$3,190,000. The mosquitoes which may have been involved in the spread of this disease in Iowa were *Aedes nigromaculis* (Ludlow), *Aedes dorsalis* (Meigen), *Aedes triseriatus* (Say), *Aedes vexans* (Meigen), and *Culex tarsalis* Coquillett. The dog heartworm, *Dirofilaria immitis* Leidy, is becoming more and more prevalent in the United States, especially in the South. Infestations in Iowa dogs, at the present time, appear to be limited to those animals which have been trained or used for hunting in the southern states. Mosquitoes serve as intermediate hosts and vectors of this parasitic worm. Iowa mosquitoes which may be important in the spread of this parasite among Iowa dogs are *Anopheles punctipennis*, *Anopheles quadrimaculatus*, *Anopheles occidentalis*, *Aedes canadensis* (Theobald), *Aedes vexans*, *Aedes cinereus* Meigen, *Aedes stimulans* (Walker), *Culex restuans* Theobald, *Culex salinarius* Coquillett, *Culex pipiens* Linnaeus, and *Culex tarsalis*. It has been known for several years that mosquitoes are able to spread the virus of fowl-pox from diseased to healthy birds. The following Iowa species are among those which have been shown to be vectors: *Culex pipiens*, *Aedes vexans*, and *Aedes stimulans*. Under certain conditions it is pos-

<sup>1</sup> Original thesis submitted March 10, 1942. Doctoral thesis number 673.

sible that the extremely infectious disease tularaemia may be spread by mosquitoes.

The systematic treatment of Iowa mosquitoes presented in the thesis includes a list of the species arranged systematically and notations regarding their comparative abundance. The more important structural characters used in identification are described and illustrated. Keys are given for the identification of larvae and adults of the tribes, genera, and species. The discussion of each species includes notes on synonymy, recognition characters, distribution, biology, and importance.

In Iowa, the aquatic habitats in which mosquitoes breed are all directly or indirectly produced by precipitation. Summer rainfall is the most important environmental factor affecting mosquito abundance, and the seasonal distribution of rainfall is important especially in regard to the species which are likely to occur. Periods of increased mosquito abundance are more frequent following continuous rains of several days' duration than following short heavy downpours. This is especially true if the total evaporation for the rain periods does not greatly exceed or is less than the total precipitation.

Over most of Iowa the topography is gently rolling, and temporary surface pools, which are suitable for the breeding of *Aedes* and *Psorophora*, are quite numerous following summer rains.

Iowa is situated in the transitional zone between the deciduous forest and the grassland prairie regions. Species of mosquitoes which are characteristic of both floral regions may be found breeding together over most of the state. Prairie species, however, are more common in the extreme western sections of Iowa, and woodland species are more common along the eastern and southern borders of the state.

Based upon gross environmental characteristics summarized from field notes the larval habitats are grouped into 12 types. These include permanent ponds, semipermanent ponds, streams, oxbows, streambed pools, woodland pools, early spring pools, rain pools and sheet water, flood water pools, marshes, foul pools and sewers, and artificial receptacles. These habitats are described and illustrated. The frequencies with which the larvae of the various species were found in these habitats are presented, and records of larval associations are given.

A study of the adult mosquito populations which occurred in 10 Iowa cities during 1940 was made. Mosquito traps were used to sample these populations. Traps were operated at Lansing, Dubuque, Davenport, Muscatine, Burlington, Ames, Des Moines, Council Bluffs, Sioux City, and Ruthven. Trap catch records are given in tabular form, and graphical figures illustrate the seasonal record of catches for each locality.

Of the total females taken in the traps 67 per cent were *Aedes*, 99 per cent of these being *A. vexans*; 29 per cent were *Culex* and about 1 per cent were *Anopheles*. With the exception of two traps, Council Bluffs and Dubuque, catches of *Aedes* were higher than were those of *Culex*. Average nightly catches ranged from 7 at Council Bluffs to 110 at Ruthven. These catches were considerably higher for the traps along the

Mississippi River than for those along the Missouri River. The percentages of trap-nights during which 24 females were taken are given as follows: Davenport, 73; Des Moines, 73; Dubuque, 64; Muscatine, 50; Ruthven, 47; Burlington, 37; Ames, 30; Lansing, 24; Sioux City, 12; and Council Bluffs, 2.

The data on seasonal occurrence indicate that periods of increased mosquito abundance follow within 10 to 20 days after periods of increased precipitation. Higher populations occurred following prolonged periods of heavy rains.

The mean temperatures were relatively high on nights when the larger catches were taken and, during periods of increased abundance, the smaller catches were generally on nights with lower mean temperatures.



## SOME FACTORS AFFECTING THE GERMICIDAL EFFICIENCY OF HYPOCHLORITE SOLUTIONS<sup>1</sup>

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The disinfecting properties of chlorine have long been known, and it is probable that at the present time chlorine, in one form or another, is used in greater amounts than all other disinfectants combined. Chlorine as a disinfectant was first used in the form of hypochlorites, and although liquid chlorine has largely replaced hypochlorites where chlorination is practiced on a large scale, the latter remain among the important disinfecting agents employed today.

The numerous conflicting results as to the relative germicidal efficiency of the hypochlorites which have been reported in recent years have probably been due to not taking into consideration some of the factors which affect the germicidal efficiency of chlorine compounds. It therefore seemed desirable to make a study of the germicidal activities of the hypochlorites under controlled conditions with respect to concentration, reaction (pH), and temperature.

*Bacillus metiens*, which has previously been employed in studies on disinfection with alkalies and chloramine-T, was considered particularly suitable for this study. By using spores of this organism, killing times of sufficient magnitude could be obtained to facilitate detection of survivors and to make possible a study of the nature of the germicidal action.

A technique has been developed for preparing suspensions of spores of *Bacillus metiens* in Butterfield's formula "C" water which maintain uniform resistance over a period of several months when stored at 10°C. However, suspensions used in this study were generally one or two days old.

The effect of concentration on germicidal efficiency was determined at 20°C., employing calcium hypochlorite (B-K) solutions with initial concentrations of 25, 100, and 500 p.p.m. available chlorine and the reaction adjusted to pH 10. The following results were obtained:

a. The average killing times (time to kill 99 per cent of the exposed *Bacillus metiens* spores) for concentrations of 25, 100, and 500 p.p.m. available chlorine, were 121, 63.5, and 31 minutes, respectively.

b. Increasing the concentration of available chlorine four times effected a reduction in killing time of approximately 50 per cent and doubling the concentration of available chlorine reduced the killing time approximately 30 per cent.

c. When the logarithms of the killing times were plotted against the logarithms of the concentrations of available chlorine, a straight line was obtained, showing that the logarithms of the killing times were inversely proportional to the logarithms of the concentrations.

<sup>1</sup> Original thesis submitted December, 1938. Doctor's thesis number 503.

d. The nature of the curves obtained by plotting the killing times against the concentrations of available chlorine shows that the effect of concentration was fairly uniform in the range under consideration.

The effect of reaction (pH) on the germicidal efficiency of calcium hypochlorite (B-K) was observed at 20°C., employing solutions containing 25 p.p.m. available chlorine at pH 6, 7, 8, 9, 9.35, 10, and 12.86 with the following results:

a. Changes in reaction below pH 8 had relatively little effect upon germicidal efficiency, the killing times being 2.5, 3.5, and 5 minutes at pH 6, 7, and 8, respectively. Above pH 8, slight changes in reaction markedly affected germicidal efficiency. In the region of pH 9 to 10, increasing alkalinity exerted a tremendous depressing effect upon germicidal power. At pH 9 the killing time was 19.5 minutes, and at pH 9.35 the killing time increased to 35.3 minutes. At pH 10 and 12.86 the killing times were 121 and 465 minutes, respectively. It will be noted that a change from pH 6 to pH 8 exactly doubled the length of the killing time, while the change from pH 8 to pH 9 increased the length of the killing time approximately fourfold.

b. When the pH was plotted against the logarithms of the killing times, the points at pH 6, 7, and 8 fell upon a straight line, showing a direct relationship between pH and the logarithms of the killing time. The points at pH 9, 9.35, and 10 similarly fell upon a straight line, but with the slope differing from that of the former, the break in the curve occurring in the region of pH 8.

The effect of temperature on the germicidal efficiency of calcium hypochlorite (B-K) solutions containing 25 p.p.m. available chlorine at pH 10 was determined at 20°, 30°, 35°, and 50°C. The results were as follows:

a. The average killing times ranged from 9.5 minutes at 50°C. to 121 minutes at 20°C. The average killing time at 35°C. was 40 minutes, and at 30°C. it was 65 minutes.

b. The killing time was shortened by about 46 to 64 per cent for each 10-degree rise in temperature, which shows that temperature is an important factor in disinfection with hypochlorites.

c. The calculated values of  $Q_{10}$  for the temperature interval 20° to 30°C. was 1.86, while for the intervals 30° to 40° and 40° to 50°C. the values of  $Q_{10}$  were 2.40 and 2.63, respectively. The reason for the increasing values of  $Q_{10}$  with increasing temperatures was not apparent.

The germicidal properties of solutions containing 25, 100, and 500 p.p.m. available chlorine prepared by diluting a sample of commercial calcium hypochlorite (B-K) with distilled water, was determined at 20°C. Rather unusual results were obtained which were as follows:

a. The killing times in the solutions with low concentrations of available chlorine were decidedly shorter than in solutions with high concentrations of available chlorine, being 35.5, 57, and 95.5 minutes for concentrations of 25, 100, and 1,000 p.p.m. available chlorine, respectively.

b. The apparently anomalous results obtained may be explained

by the fact that dilution of the hypochlorite solutions employed increased the hydrogen-ion concentration. The reaction (pH) of the solution containing 1,000 p.p.m. available chlorine was  $\text{pH } 11.1 \pm 0.1$ , but when diluted to 100 p.p.m. available chlorine, the pH dropped to 9.75 and to pH 9.35 when diluted to 25 p.p.m. available chlorine. This indicates that reaction (pH) is a much greater factor in disinfection with hypochlorites than is the concentration of available chlorine.

# AN INVESTIGATION OF THE FOOD COACTIONS OF THE NORTHERN PLAINS RED FOX<sup>1</sup>

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Here reported are the results of an investigation in which the Northern Plains red fox (*Vulpes regalis* Merriam) was examined as a living organism in a studied environment. The research was accomplished by field and laboratory methods involving some experimentation with captive animals. The intensive field work was carried out on the Moingona Fox Range in the Des Moines River Valley in central Iowa while occasional observations were made contemporaneously in other parts of the state. The research extended through the period from June, 1938, to July, 1941.

The coactions<sup>2</sup> resulting from the feeding of the red fox on its plant and animal associates formed the focal point of attention. Research on the foods of red foxes has had a strong seasonal bias, work usually being carried on in only one or two seasons. This study sought to obtain data with greater depth through continuous observation over a period of three years. The meaning of food availability was broadly engaged in this investigation because there is a tendency for predation to be proportional to the numbers of available prey (McAtee, 1933). Furthermore, as popular belief held that red foxes possessed remarkably efficient hunting prowess it was important to attempt an evaluation of the extent to which the foxes influenced the trends of prey animal populations.

For a background the study has the extensive research on red foxes in Iowa by Errington (1935 and 1937) and many general notes contemporaneously gathered on other fox ranges. There is considerable literature on red foxes and closely related forms of wild dogs, and references affecting the principles of predation are accumulating.

Observations in the field were most productive when concentrated upon the evidences of "signs" left by the red fox in its life's activity. The techniques employed in locating, recognizing, and interpreting these "signs" were discussed in detail. The home range, movements, and life history of the red foxes were importantly related to the food interrelationships. Home range and movements were reflected in the diet because the animals naturally fed within the limits of their living space. Feeding behavior was examined in an effort to understand something of species vulnerability.

The feeding tendencies were investigated by analysis of fecal passages because the number of samples available made possible a continuous de-

<sup>1</sup> Original thesis submitted March 17, 1942. Doctoral thesis number 676.

<sup>2</sup> The word coaction has been used by Clements and Shelford (1939, p. 103) "—to designate the enormous range of interactions among plants, plants and animals, and animals alone, since it involves not only the idea of acting together, but also that of urging or compelling."

termination of the relative proportions of the foods consumed. During the study 1,454 fecal passages were collected and analyzed; 234 of these were picked up at dens. The latter were used as evaluations of the effect of early life on the feeding tendencies of red foxes.

The red foxes were found to be primarily carnivorous with substantial quantities of insect and plant foods being consumed when available. Warm-blooded vertebrates were less frequent in the warm weather diet than in the cold weather diet, whereas, the reverse was true for insects and plant foods. The principal staple foods were cottontails and mice, especially *Peromyscus* and *Microtus*.

The red foxes seemed to have food preferences. The meadow mouse was high on the scale of preferences. Insectivores and weasels were regularly left uneaten. Weasels appeared to be particularly unsatisfactory as food. Carrion that was advanced in decay did not seem to be attractive food for the foxes.

Differences were noted in a comparison of the frequency of occurrences of the principal food groups in the fecal passages from the trails and those from the dens. In April, when the pups were most dependent upon the adults for food, the remains of warm-blooded vertebrates were more frequent in the fecal material from the dens than that from the trails. At the same time limited occurrences of invertebrate and plant remains were detected in passages from the trails while neither was found in passages from the dens. In May, when the pups were presumably less dependent on the adults, warm-blooded vertebrates were not so frequent in the den material and were more frequent in that from the trails. Also, in May the invertebrate and plant representations markedly increased in the passages found at the dens.

Within the limits of its fundamentally carnivorous nature the red fox was mainly influenced in its feeding by availability. It was obvious that the foods consumed must first have been available. On the whole the proportions of individual food items, however, seemed to respond more to the relative availabilities of all items in the diet than to their specific availabilities. Fluctuations occurred in the frequency of occurrences of some foods for which no appreciable change in availability was evident simply because other foods became relatively more or less available.

There seemed to be no important lack of utilization of suitable foods. The foxes ate carrion not too far advanced in decay, and frequently items that they killed and did not eat were readily consumed by animal associates. So far as could be determined these foxes did not exert a dominant influence upon the populations of the prey animals regularly consumed. The direction of seasonal annual population trends seemed to continue unchanged by the pressure of fox predation.

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## THE MICROBIOLOGICAL FORMATION OF ACETYLMETHYLCARBINOL<sup>1</sup>

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The currently accepted theory regarding the enzymatic formation of acetylmethylcarbinol from pyruvic acid assumes a carboxylatic cleavage of the acid to acetaldehyde and CO<sub>2</sub>, and consequent condensation of two moles of the aldehyde to carbinol by the enzyme carboligase. This theory has been built up, for the most part, from studies employing dried yeast and yeast juices as a source of enzyme. Experimental evidence obtained by the application of a cell-free enzyme preparation extracted from *Aerobacter aerogenes* does not confirm the theory established with the use of yeast. The cell-free enzyme preparation from *Aerobacter* quantitatively converts pyruvic acid into CO<sub>2</sub> and acetylmethylcarbinol according to the following equation:



Yeast carboxylase does not require inorganic phosphate for activity and yields acetaldehyde as a product of pyruvic acid cleavage. The carbinol enzyme system from *Aerobacter* requires inorganic phosphate prior to cleavage of CO<sub>2</sub> from pyruvate, and does not yield acetaldehyde as a product of this cleavage. These results indicate that an enzyme similar to yeast carboxylase does not participate in the formation of carbinol in the *Aerobacter* system.

The existence of the enzyme carboligase in yeast has been questioned by Dirscherl (1937). No evidence for its presence in the *Aerobacter* carbinol system has been found. This system does not utilize acetaldehyde either in the presence or absence of pyruvic acid. Studies made by means of chemical inhibitors and physical treatments (heating and ultracentrifugation) indicate that the carbinol enzyme system of *Aerobacter* cannot be separated into a carboxylase and a carboligase.

Inasmuch as inorganic phosphate is essential for the formation of acetylmethylcarbinol by the enzyme investigated, studies based on the effect of inorganic phosphate indicate that, rather than acetaldehyde, a phosphorylated organic compound occurs as an intermediate in the enzymic formation of acetylmethylcarbinol from pyruvic acid. Lipmann (1939) has suggested that acetylphosphate is the intermediate involved in the formation of acetic acid from pyruvic acid by preparation of *Lactobacillus delbrückii*. Attempts to enzymatically synthesize diacetyl or acetylmethylcarbinol from acetylphosphate in the presence of acetaldehyde and formate as hydrogen donors were unsuccessful.

An acid reaction is essential for both the formation of the acetylmethylcarbinol enzyme in *Aerobacter* during growth and for the optimum

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 644.

activity of the cell-free enzyme system. If the growth medium is maintained at an alkaline reaction little or none of the enzyme is formed as evidenced by its absence on attempted extraction. Above pH 7.2, the cell-free enzyme system is inactive on pyruvate, and the latter may be recovered unchanged. The enzyme appears to be most active in the vicinity of pH 5.6.

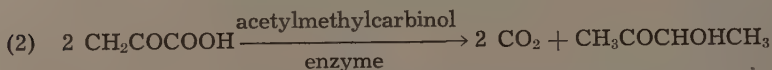
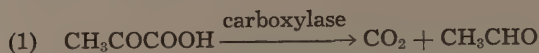
In addition to inorganic phosphate and an acid reaction, the enzyme protein requires either  $Mn^{++}$  or  $Mg^{++}$  and cocarboxylase.  $Mn^{++}$  is a far better stimulant of the system than is  $Mg^{++}$ . When the system is saturated with cocarboxylase, no stimulating effect of  $Mn^{++}$  can be demonstrated, indicating a close physiological relation between  $Mn^{++}$  and cocarboxylase.

From a study of the gas ratios resulting from the activity of *Aerobacter aerogenes* cells acting on pyruvic acid, it has been shown that two enzyme systems compete for the available pyruvic acid. The two systems involved are the acetylmethylcarbinol ( $2 CH_3COCOHOH \rightarrow 2 CO_2 + CH_3COCHOHCH_3$ ) and the hydroclastic ( $CH_3COCOHOH \rightarrow CH_3COOH + HCOOH$ ). The distribution of pyruvic acid between these two systems is governed by pH; the carbinol system being active at only acid reactions, whereas the hydroclastic system is active in both acid and alkaline ranges. At pH 8.0 the acetylmethylcarbinol system is almost completely suppressed resulting in a  $CO_2/H_2$  ratio approaching 1.0, since the gases must arise in equimolar proportions from formic acid. At more acid reactions, gaseous products arise as a result of the activity of both systems; therefore, the  $CO_2/H_2$  ratios become greater than 1.0 since only carbon dioxide and no hydrogen arises from the action of the carbinol enzyme.

Based on experimental evidence obtained by other workers, conclusions are drawn as to the mode of action of acetic acid and its analogues and that of acetyldehyde and its analogues in increasing carbinol yields in bacterial fermentations of glucose. An examination of their data shows that in all cases where higher carbinol yields are obtained in the presence of acetic acid or acetaldehyde, the yields of hydroclastic products are decreased. These data have frequently been interpreted to indicate that the acids or aldehydes have been converted into the carbinol or its reduction product 2,3-butylene glycol. The same data are, however, subject to another interpretation, simply that the acids or aldehydes tend to inhibit those enzymes that compete with the acetylmethylcarbinol enzyme for intermediately formed pyruvic acid. It has been shown for *Aerobacter* that two systems compete for this acid.

Preliminary evidence has been obtained showing that two systems in yeast may cleave carbon dioxide from pyruvate. This evidence is based on results obtained by the use of dried fresh yeast cells. Undried fresh yeast cells in the resting state will not form acetylmethylcarbinol from pyruvic acid in phosphate buffers. About 75 per cent of a considerable number of fresh yeasts when dried do form the carbinol under the same conditions. Examination of one strain of such a yeast shows that

when it is dried, the rate of  $\text{CO}_2$  production from pyruvate is about double that of the undried yeast; at the same time, carbinol was formed by the dried yeast and not by the undried yeast. Apparently, drying activates the carbinol mechanism in yeast. At present the action of the two systems in yeast, postulated as cleaving  $\text{CO}_2$  from pyruvate, may be indicated as follows:



The first reaction represents the action of the familiar carboxylase of yeast. The second represents the acetylmethylcarbinol system similar or identical to that of *Aerobacter*. If conclusive evidence finally shows the above two systems are active in the yeast cell, the rôle of acetaldehyde in the formation of acetylmethylcarbinol by dried yeast can be explained. Acetaldehyde acts by simply inhibiting the enzyme carboxylase, making available more of the pyruvic acid to the acetylmethylcarbinol system.

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# INTERMEDIARY METABOLISM OF CERTAIN HETEROTROPHIC BACTERIA, PARTICULARLY *STREPTOCOCCUS PARACITROVORUS* AND *AEROBACTER INDOLOGENES*<sup>1</sup>

HUTTON DAVISON SLADE

*From the Department of Bacteriology, Iowa State College*

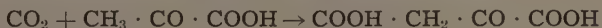
## FERMENTATION OF CITRIC ACID

The mechanism of the anaerobic dissimilation of citric acid by cell suspensions of *Streptococcus paracitrovorus* has been investigated. The products formed from citrate at pH 6.6 include CO<sub>2</sub>, H<sub>2</sub>, and formic, acetic, lactic, and succinic acids. The qualitative and quantitative nature of the products formed from oxalacetic and pyruvic acids, leads to the proposal that the latter compounds function as intermediates in the dissimilation of citrate by *S. paracitrovorus*. A scheme of dissimilation is presented. Azide, arsenite, and iodoacetate effectively inhibit the fermentation of citric, oxalacetic, and pyruvic acids.

An acid reaction (pH 3.5-5.7) is necessary for the formation of acetylmethylcarbinol and 2, 3-butylene glycol from citric acid. As the acidity of the medium is increased, the total yield of the carbinol and glycol increases, while the yields of acetic acid and succinic acid decrease. The total amount of C<sub>4</sub> compound is, however, practically the same in each case.

## ASSIMILATION OF C<sup>13</sup>O<sub>2</sub> BY CERTAIN HETEROTROPHIC BACTERIA

The concept of the assimilation of carbon dioxide by heterotrophic bacteria is due, in large measure, to the investigations of Wood and Werkman (1, 2, 3). The proposal was advanced that CO<sub>2</sub> was fixed by heterotrophic bacteria according to the following reaction:



Studies with C<sup>13</sup> (4) have confirmed the principle of the fixation reaction.

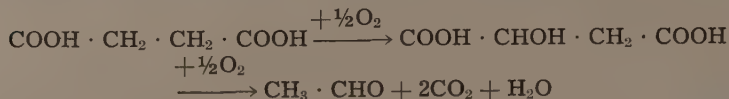
It has been the purpose of this investigation to determine the extent of CO<sub>2</sub> assimilation among heterotrophic bacteria, the extent of C<sub>3</sub> and C<sub>1</sub> addition, and the possibility of assimilation by other mechanisms.

Assimilation of CO<sub>2</sub> with the formation of a carbon to carbon linkage is established as a general phenomenon among various heterotrophic bacteria. It is shown by the use of heavy carbon, C<sup>13</sup>, as a tracer, that the fixed carbon is located in the carboxyl groups of succinic, lactic, and acetic acids. The assimilated carbon is distributed as follows: *Aerobacter indologenes*, acetate, lactate, and succinate; *Proteus vulgaris*, *Streptococcus paracitrovorus*, and *Staphylococcus candidus*, lactate and succinate;

<sup>1</sup> Original thesis submitted June, 1942. Doctor's thesis number 687.

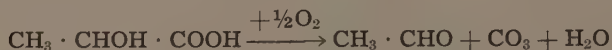
*Clostridium welchii*, acetate and lactate; *Clostridium acetobutylicum*, lactate.

Succinic acid contained assimilated carbon in every case in which it was formed. This fixation is believed to arise by  $C_3$  and  $C_1$  addition according to the Wood and Werkman reaction. The fixed carbon in succinate was located according to the following reactions:



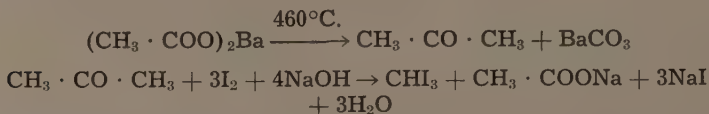
Acetaldehyde originates from the methylene carbon atoms and  $\text{CO}_2$  from the carboxyl carbon atoms of succinic acid.

Conversely, lactic acid did not contain fixed carbon in every case in which it was formed. Two possible mechanisms are suggested to explain the fixation of  $\text{CO}_2$  in the carboxyl group: (1)  $C_2$  and  $C_1$  addition, and (2) a secondary conversion of a  $C_4$  dicarboxylic acid containing fixed carbon in the carboxyl group. The latter possibility appears most likely. The fixed carbon was located as follows:



Acetaldehyde originates from the  $\alpha$ ,  $\beta$  carbon atoms and  $\text{CO}_2$  from the carboxyl carbon atom of lactate.

Acetic acid containing fixed carbon in the carboxyl group was produced by *Aerobacter indologenes* and *Clostridium welchii*. The suggestion is made that the acetic acid may arise by an oxidative cleavage of a  $C_4$  dicarboxylic acid containing fixed carbon in the carboxyl group into two  $C_2$  molecules. The fixed carbon in acetate was located as follows:



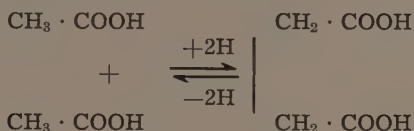
The carbonate originates from the carboxyl carbon atom and iodoform from the methyl carbon atom of acetic acid.

#### ASSIMILATION OF ACETIC ACID AND SUCCINIC ACID CONTAINING HEAVY CARBON BY AEROBACTER INDOLOGENES

Acetic and succinic acids were added to fermentations of glucose by cell suspensions of *A. indologenes*. The addition of succinic acid ( $\text{C}^{13}\text{OOH} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{COOH}$ ) results in the formation of acetic acid, ethyl alcohol, and 2, 3-butylene glycol, each containing  $\text{C}^{13}$ . Acetate is formed by a cleavage of succinate into two molecules of a  $C_2$  compound which are isolated as acetic acid.

The addition of type 1 acetic acid ( $\text{CH}_3 \cdot \text{C}^{13}\text{OOH}$ ) results in the formation of succinic acid, 2, 3-butylene glycol, and ethyl alcohol, each

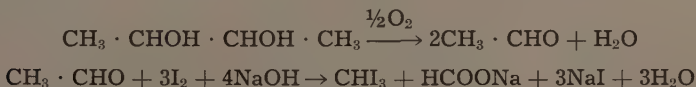
containing  $C^{13}$ . Succinate contains  $C^{13}$  exclusively in the carboxyl carbon atoms. Hence, the succinate is formed by means of a carbon to carbon linkage involving the methyl carbon atom of acetic acid. The general reaction may be represented as:



The addition of type 2 acetic acid ( $C^{13}\text{H}_3 \cdot C^{13}\text{OOH}$ ) also results in the formation of succinic acid, 2, 3-butylene glycol, and ethyl alcohol, each containing  $C^{13}$ . Succinate contains  $C^{13}$  equally distributed in the methyl and carboxyl carbon atoms.

These results prove a condensation of  $C_2$  compounds originating from acetic acid to a  $C_4$  compound which is isolated as succinic acid. Inasmuch as the initial compound is acetic acid and the end product is succinic acid, the reaction probably involves acetic acid condensation.

The 2, 3-butylene glycol formed in the presence of type 1 acetate contains  $C^{13}$  exclusively in the hydroxyl carbon atoms. This proves that a carbon to carbon linkage is created in the synthesis of the glycol which involves the carbon atom of a  $C_2$  compound originally present in the carboxyl group of acetic acid. The fixed  $C^{13}$  was located as follows:



Iodoform originates from the methyl carbon atom and formic acid from the hydroxyl carbon atom of the glycol.

The glycol formed in the presence of type 2 acetate contains  $C^{13}$  equally distributed between the methyl and hydroxyl carbon atoms. The results prove, and present direct evidence that a  $C_2$  compound, probably acetaldehyde formed by a reduction of acetic acid, is involved in the synthesis of 2, 3-butylene glycol by the intact cell of *Aerobacter*.

Acetic acid is also reduced to ethyl alcohol. Acetaldehyde is probably an intermediate in this reduction. Approximate calculations show that the condensation of acetic acid to succinic acid and the reverse reaction, the conversion of acetic acid to 2, 3-butylene glycol, and the reduction of acetic acid to ethyl alcohol, are reactions which possess quantitative significance under the experimental conditions.

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# ECOLOGY AND MANAGEMENT OF THE AMERICAN COOT *FULICA AMERICANA AMERICANA* GMELIN<sup>1</sup>

CLARENCE A. SOOTER

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The investigation on the American coot, *Fulica americana americana* Gmelin, was carried on at Dan Green's Slough, Clay County in northern Iowa. This slough is located in what is known as the "Ruthven Area" which consists of a number of marshes and lakes within a 10-mile radius of Ruthven, Iowa.

Green's Slough was selected for the principal investigations because it was representative of Iowa coot nesting habitat. Supplemental observations were made on other nearby waterfowl areas.

The purpose was to obtain further data on the life history, habits, characteristics, and various factors affecting the coot so that the bird would come more into its place among our game birds. Studies were also directed toward finding more practical management methods for aiding in an increased production of this bird and other waterfowl.

Coots migrated during the night and arrived with the earliest spring migrant ducks that reached the northwest Iowa marshes shortly after the ice began to disappear, about March 20, 1936 and 1937. Approximately 100,000 coots migrated through the "Ruthven Area" during the 1937 spring migration. Coots completed their summer molt about September 1, and fall migration began shortly thereafter. There were five distinct coot remigrations away from Goose Lake, Hamilton County, during the fall, 1936. The majority of the coots left the small lake as soon as the hunting season opened. One coot was timed at 25 miles per hour and other coots were seen flying two or three miles per hour faster. No mass migration of coots was observed.

One of 55 juvenile coots banded in the summer 1936, was shot in Florida, November 30, 1936. This was the only return. At the time this coot was banded, July 21, it weighed six ounces and was estimated to be two and one-half weeks old.

Coots began their courting tactics about April 11, 1937, on Dan Green's Slough. Paired coots fought and chased others of their species from selected territories. Ducks were sometimes chased by coots from their nesting territories, and perhaps some of the timid were driven to nest in territories other than those they would have selected. Shortly after this they built crude raft-like structures which were sometimes used in courtship, and then turned into nests or abandoned. The first coot nest on Green's Slough was found May 6 and it was the first to begin hatching, May 31. The 1936 and 1937 nesting seasons ended the first week in August.

There were two distinct nest hatching peaks in 1937. This was attri-

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<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 648.

buted to renesting after many nests had been destroyed during the early part of the nesting season.

Except for one nest which hatched two clutches, a nest was built for each clutch of eggs. Eggs were laid at a rate of one per day and deposited in the nest shortly after midnight. Incubation began as soon as the first eggs were laid, and because both sexes took turns at the nest the eggs were incubated continuously.

The clutches contained from 1 to 18 eggs, with an average of 6.08 eggs for 104 clutches in 1936, and 7.92 eggs for 345 clutches in 1937. Nests contained an average of approximately two eggs more per clutch during the first half of the nesting season than during the last part of the season in 1937. In eight coot nests, from each of which all eggs but one were removed at intervals of five to seven days an average of 15.88 eggs were laid, varying from 14 to 18.

Nests were 9 to 18 inches in outside diameter, and 5 to 10 inches in inside diameter. The rims of the nests were 2 to 8 inches above the water, and the nest cups were 0 to 5 inches deep. No nest was found with a cupola or similar structure. A large number had ramps or runways.

Coot nests were situated in emergent vegetation an average of 18 yards from an edge of wide open channels or large open pools. Narrow lanes of water were discernible between the nests and wide channels or large pools.

Both parents shared in the duties of rearing the young. No coot was observed to go to extremes in protecting young. Adult coots were antagonistic toward coot chicks not of their brood. Coot chicks soon learned to forage for themselves but preferred to be fed by adults as long as they would do so.

In 1936, 91 per cent of the clutches under observation hatched, and in 1937, 77 per cent hatched. The weather destroyed more nests than any other agent, although coots reinforced their nests during stormy weather. Birds (particularly crows and terns) were responsible for 10 per cent of the nest destruction in 1937. Muskrats caused 5 per cent of the nest destruction in 1937 and may have caused a number of the desertions recorded. In 1937, 17.5 per cent of the nests under observation were deserted.

Approximately two young were produced by each pair of coots nesting on Dan Green's Slough in 1937.

Leeches were known to cause the deaths of five coots in the "Ruthven Area." Other than that, no coot loss from parasites or diseases was noted.

The majority of the marshes in northwest Iowa supported stands of emergent vegetation that served as excellent nesting and rearing cover for coots. Deep water and other agents were noted causing eradication of emergent stands of vegetation in Dan Green's Slough. The most important plants used by coots as nesting and rearing cover were: hardstem bulrush, giant bur reed, sweet flag, reed grass, river bulrush, sedge, and cattail. There was an average of 1.51 nests per acre on 224 acres, the area of Green's Slough in 1937, and 3.28 nests per acre on the 109 acres of vegeta-

tion of the slough. Only a small per cent of the nests were situated in very dense or very sparse stands of vegetation.

Food of coots consisted largely of available plant material. The four most common families represented in stomach examinations were: pondweed, sedge, smartweed, and hornwort. Animal food material was more important in the diet of juvenile coots than in that of adults.

It was estimated 3.19 coots per acre were produced in 1937 on Green's Slough.

Nest censusing can be simplified by making counts of birds on sample areas and correlating numbers seen with nesting studies made at the same time.

The coot is a game bird that should be recognized for its true value by sportsmen, and when properly cooked, coot meat is as good as that of ducks.

The marshes of northwest Iowa would produce more coots and other waterfowl if fenced against livestock. For coots open pools of about one-fourth acre in area and channels at least 10 feet wide at intervals of about eight rods would provide feeding places. Emergent vegetation between the channels and pools would provide nesting and escape cover. Muskrats from which a surplus might be harvested for profit, and to a lesser extent mechanical methods (dams, dredges, and dynamiting) might be used to remove excessive plant growth.

# APPLICATION OF LITHIUM COMPOUNDS OF NITROGEN HETEROCYCLES TO ANTIMALARIAL SYNTHESES<sup>1</sup>

SYDNEY MARTIN SPATZ

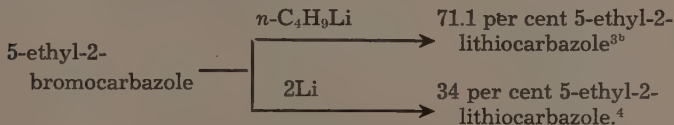
*From the Department of Chemistry, Iowa State College*

## A. LITHIUM COMPOUNDS OF NITROGEN HETEROCYCLES

The organolithium and Grignard reagents are the most useful organometallics in synthetic chemistry. Unfortunately, not all RLi or RMgX compounds can be made by the customary reaction of a metal on RX. However, by application of the recently developed<sup>2</sup> halogen-metal interconversion reaction,



previously inaccessible organometallics, such as the pyridyl- and quinolylithium compounds, the dilithiocarbazoles, and halogen-containing organometallics of pyridine and carbazole were prepared. Specifically, and with yields, these are<sup>3</sup>: 2-pyridyllithium (62%), 3-pyridyllithium (30–45%), 5-bromo-3-pyridyllithium (40–45%), 6-bromo-2-pyridyllithium (40–45%), 3-quinolylithium (52%), 2-lepidyllithium (28–53%), 2-lithiocarbazole (57.8%), 5-ethyl-2, 8-dilithiocarbazole (84%), and 2-iodo-5-ethyl-8-carbazolylmagnesium bromide (3.7%). Furthermore, previously known organometallics of carbazole were made available in decidedly improved yields. For example,



The  $X - M$  reaction in the nitrogen heterocycles is applicable only where  $X = \text{Br}$  or  $\text{I}$ . Despite the exalted reactivity of  $\alpha$ - and  $\gamma$ -chloro atoms in the pyridine and quinoline series, the attempted interconversions of 2-chloroquinoline with alkylolithium were negative. Similarly, no  $X - M$  interconversions were observed between 6-methoxy-4-chloroquinoline and phenyl-, *m*-chlorophenyl-, or *p*-chlorophenyllithium, or with 4-chloroquinoline and *o*-anisyllithium.

The chief difficulty with organometallic formation in the pyridine series arises from the presence of the azomethylene linkage, which com-

<sup>1</sup> Original thesis submitted December, 1941. Doctoral thesis number 667.

<sup>2</sup> (a) Gilman and Jacoby, *J. Org. Chem.*, **3**, 108 (1938); (b) Gilman and co-workers, *J. Am. Chem. Soc.*, **61**, 106 (1939) and subsequent papers; (c) Wittig and co-workers, *Ber.*, **71**, 1903 (1938) and subsequent papers.

<sup>3</sup> (a) Gilman and Spatz, *J. Am. Chem. Soc.*, **62**, 446 (1940); (b) *ibid.*, **63**, 1553 (1941); (c) *ibid.*, **64**, 000 (1942).

<sup>4</sup> Gilman and Kirby, *J. Org. Chem.*, **2**, 146 (1936).

petes with the halogen atom for the  $\text{RLi}$  agent. A theory of  $X-M$  reactions in compounds containing the  $-\text{N}=\text{C}<$  linkage is described. This theory predicts that the more negative groups (chlorine atom, phenyl and benzo radicals, etc.) there are in the molecule, and the more closely these are situated to the  $-\text{N}=\text{C}<$  bond, the smoother will be the  $X-M$  reaction in consequence of anil deactivation by the negative groups.

When a halogenated pyridine (or quinoline) is treated with an alkyl-lithium compound under mild conditions of time and temperature, the two prevailing reactions are  $X-M$  interconversion and  $\text{RLi}$  addition to the  $-\text{N}=\text{C}<$  bond. Generally, the former predominates, but the dominance may be reversed. Metalation occurs to a negligible extent, if at all, and evidence exists for the occurrence of an undetermined amount of coupling.

Substitution of *n*-butyllithium with  $\text{RLi}$  compounds, such as *t*- or *s*-butyllithium, which combine speed of  $X-M$  interconversion with steric factors, does not reduce the extent of anil addition in the preparation of 3-pyridyllithium from 3-bromopyridine.

Whereas, dihalogenated carbazoles undergo di-interconversion with *n*-butyllithium, the dibromopyridines undergo mono-interconversion. Mono-interconversion of a polyhalogenated carbazole can be effected by the use of a weak interconverting agent such as methylolithium or *n*-butylmagnesium bromide. The mono-interconversion studies suggest that the multiple  $X-M$  reactions of polyhalogenated compounds proceed stepwise.

$X-M$  interconversion precedes lateral metalation, as indicated by the behavior of  $\alpha$ -iodolepidine toward *n*-butyllithium.

Metalation of aromatic amines by organoalkali compounds occurs almost invariably *ortho* to the nitrogen atom or to the group containing the nitrogen atom. This rule is based on the behavior of a variety of primary, secondary, and tertiary amines. The exception is the *meta* metalation of triphenylamine.<sup>5</sup> Reasons, detailed in the thesis, indicate that the anomalous behavior of triphenylamine is the result of steric hindrance from the two large phenyl groups. Hence, replacement of one of the phenyl groups by a much smaller one, such as the methyl radical, should effect resumption of orthodox metalation. Such is the case: carbonation of the *N*-methyl-diphenylamine-butyllithium reaction yields 1.8 g. (7.9%) of *N*-methyl-*N*-phenylanthranilic acid, m.p. 103–4°. The position of *ortho* metalation was ascertained, (1) by ring closure of the acid to *N*-methyl-acridone, and (2) by *N*-methylation of *N*-phenylanthranilic acid to the metalation product described above.

Cyclohexyldiphenylamine (m.p. 74–75.5°), prepared by the *N*-phenylation of *N*-cyclohexylaniline, was metalated with *n*-butyllithium. The acid, isolated after carbonation, could not be purified for identification. Consistent with the steric aspects of the metalation of amines is the behavior of certain *N*-alkylcarbazoles. Whereas, *N*-ethylcarbazole undergoes mono-metalation only, even with a large excess of metalating agent,<sup>4</sup>

<sup>5</sup> Gilman and Brown, *J. Am. Chem. Soc.*, 62, 3208 (1940).

the treatment of *N*-methylcarbazole with one equivalent of *n*-butyllithium yields both a monobasic (m.p. 185°) and a dibasic (m. p. 252–4°) acid. The larger ethyl group makes di-metalation more difficult.

3-Quinolinecarboxylic acid is now available in quantity: (1) by *X* — *M* interconversion of 3-bromoquinoline, followed by carbonation, in 52 per cent yield; and (2) by hydrolysis in 98 per cent yield of 3-cyanoquinoline, which in turn is obtainable from 3-bromoquinoline and CuCN in 84 per cent yield. Because of its homologous relation to nicotinic acid, it may be the starting material for new pharmaceuticals. For example, *N*, *N*-di-isopropyl-3-quinolinecarboxamide and *N,N*-diallyl-3-quinolinecarboxamide possess analgesic action, the latter being about one-third as active as codeine.

## B. ANTIMALARIAL SYNTHESSES

The relationship between chemical constitution and antimalarial action is discussed in detail. In general, quinoline compounds of the plasmoquine type are gametocidal, whereas, acridines of the atebriane type are schizontocidal. Atebrine may be looked upon as a chlorobenzo derivative of 6-methoxy-4-dialkylaminoalkylaminoquinoline. It was therefore hoped that, through replacement of the chlorobenzo group by a chlorophenyl group, the resulting quinoline molecule would incorporate the biological properties of both the quinoline and acridine medicaments. To effect the proposed change in chemical structure, 6-methoxyquinoline was treated with *m*-chlorophenyllithium at 0°, the latter having been prepared by *X* — *M* interconversion from *m*-chlorobromobenzene. This procedure introduced the *m*-chlorophenyl group into the 2- position of 6-methoxyquinoline through anil addition of the RLi compound. The yield of 6-methoxy-2-(3'-chlorophenyl) quinoline (I), m.p. 110–111°, was 49–53 per cent. Picrate, m.p. 196–7°. Oxidation of I with perbenzoic acid in chloroform gave a 67 per cent yield of 6-methoxy-2-(3'-chlorophenyl)quinoline-N-oxide (II) melting at 153–4°. Picrate, m.p. 158.5–159°. 4-Chloro-6-methoxy-2-(3'-chlorophenyl)quinoline (III), m.p. 153–4°, was obtained from II and an excess of phosphorus oxychloride in 63 per cent yield. The anil addition reaction between *m*-chlorophenyllithium and 4-chloro-6-methoxyquinoline also yielded III in 34.7 per cent yield, thus establishing the position of the N-oxide halogenation. Condensation of III with 2.4 equivalents of 1-diethylamino-4-aminopentane by heating the two reactants at 200–5° for 100 hours gave a 60.7 per cent yield of 6-methoxy-2-(3'-chlorophenyl)-4-[( $\alpha$ -methyl- $\delta$ -diethylaminobutyl) amino] quinoline (IV), which was obtained as a yellow, amorphous powder. The compound is soluble in cold ethanol, forming a brown solution with a marked greenish fluorescence.

To study the effect of a shift of the chlorine atom in IV, 6-methoxyquinoline was treated with *p*-chlorophenyllithium to give a 50.2 per cent yield of 2-(4'-chlorophenyl)quinoline (V), m.p. 194–5°. Picrate, m.p. 205°. Oxidation of V to the corresponding N-oxide (VI), m.p. 166–8°, was effected in 55 per cent yield. The latter was chlorinated to 4-chloro-6-



methoxy-2-(4'-chlorophenyl) quinoline (VII), m.p. 163.5–164°, in 76.5 per cent yield. The position of halogenation was ascertained by comparison with an authentic specimen prepared from the  $\alpha$ -*p*-chlorophenylation of 6-methoxy-4-chloroquinoline in 48 per cent yield. Treatment of VII with 1-diethylamino-4-aminopentane gave a 69 per cent yield of 6-methoxy-2-(4'-chlorophenyl)-4-[ $\alpha$ -methyl- $\gamma$ -diethylaminobutyl]amino]quinoline. The yellow amorphous powder is soluble in cold ethanol, forming a brown solution with blue-green fluorescence.

To ascertain whether the chlorine atom is essential for the maintenance of biologic activity, 6-methoxy-2-phenyl-4-[ $\alpha$ -methyl- $\delta$ -diethylaminobutyl]amino]quinoline was prepared in 69 per cent yield in the manner described above from 4-chloro-6-methoxy-2-phenylquinoline (VIII). The latter was synthesized as follows: 6-methoxyquinoline and phenyllithium gave a 66 per cent yield 6-methoxy-2-phenylquinoline (IX), m.p. 132–3°. Picrate, m. p. 205°. IX gave a 55–65 per cent yield of the N-oxide, m. p. 170–1°, which was converted in 81–91 per cent yield to VIII by the action of POCl<sub>3</sub>. The position of chlorination was determined by comparison with an authentic specimen prepared by the  $\alpha$ -phenylation of 4-chloro-6-methoxyquinoline in 61.5 per cent yield.

It was also desired to study the effect of transposing the methoxy group from the quinoline ring to the phenyl nucleus. Accordingly, 2-(2'-methoxyphenyl)-4-[ $\alpha$ -methyl- $\delta$ -diethylaminobutyl]amino]quinoline (b.p. 248–255° at 0.025 mm.) was prepared by condensation of 4-chloro-2-(2'-methoxyphenyl)quinoline (X) with the aliphatic amine. X was prepared through the following sequence of reactions: *o*-anisyllithium, prepared from *o*-bromoanisole by X — M interconversion with *n*-butyllithium, was treated with quinoline at –14° to give a 41.2 per cent yield of 2-(2'-methoxyphenyl) quinoline (XI), b.p. 201–4° at 2 mm. Hydrochloride, m.p. 184.5–185°. Picrate, m.p. 177–8°. XI was oxidized to the N-oxide (XII), m.p. 178–178.5° in 64–68.6 per cent yield. Picrate of XII melted at 133.5–134.5°. The N-oxide was converted to X, m.p. 96–8°, in 56.5 per cent yield. The picrate of X melted at 200–201°. A mixed m.p. of X with an authentic specimen prepared by the  $\alpha$ -arylation of 4-chloroquinoline with *o*-anisyllithium showed no depression.

The mechanism of N-oxide halogenation is treated in detail.

## FOOD HABITS OF SHOREBIRDS (CHARADRIIFORMES) IN NORTHWESTERN IOWA<sup>1</sup>

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The past several decades in the history of North America migratory birds have shown that the shorebirds (Charadriiformes), like several other orders, have suffered great reductions in numbers. These birds, at one time very abundant, as legitimate game were taken in large numbers by market hunters, a practice which contributed greatly to their steady decline.

This situation has been remedied somewhat by the Migratory Bird Treaty Act of 1918 as amended by Act of 1936. In addition, the system of migratory bird refuges established by the United States Fish and Wildlife Service has been an important step toward increasing shorebird breeding stock and the improvement of areas for use during the spring and fall migrations.

A knowledge of the food habits of a species of bird is quite essential in the establishment of an effective management program. Most references pertaining to this subject present information which is apparently based upon specimens taken from the country at large rather than from any one specific locality. Recommendations for management should be made only after consideration of conditions which are more local in nature and should be based upon facts which pertain to those localities, and similar areas, in which the management is to be practiced.

In this investigation 152 shorebird stomachs were examined. With the exception of two birds these were taken in the Ruthven area, Clay and Palo Alto Counties, Iowa. They were collected mainly during the fall of 1934. This number represents four species: (1) Wilson's snipe, *Capella delicata* (Ord.); (2) dowitchers, *Limnodromus griseus* subspecies *griseus* (Gmelin) and *scolopaceus* (Say); (3) lesser yellowlegs, *Totanus flavipes* (Gmelin); and (4) greater yellowlegs, *Totanus melanoleucus* (Gmelin).

The problem was undertaken for three reasons: (1) that information might be obtained relative to the local food habits of these species; (2) that a comparison might be made between snipe and dowitchers, two species which are morphologically similar yet which show different habitat preferences; and (3) that the food habits of these two species might be compared with those of a morphologically different species: lesser yellowlegs.

In making the analyses of the stomachs the taxonomic specimen-enumeration method was used. The results of the analyses are given in tables, which show the kinds of food taken, the number of birds in which each item occurred, the total number of specimens of each item taken, and the percentage of birds, in each case, in which these were found.

<sup>1</sup> Original thesis submitted December 16, 1941. Doctoral thesis number 658.

Stomachs of 67 snipe were examined. Insects were represented in 93.65 per cent of the birds. Fly larvae (Diptera) were found in 64.18 per cent, with Dolichopodidae, Stratiomyidae, Muscidae, and Chironomidae taken by progressively smaller percentages of the birds. The larvae of water scavenger beetles (Hydrophilidae) were also important. Other animals foods represented were: other flies and beetles, bugs (Hemiptera), ants (Hymenoptera), a moth (Lepidoptera), bird lice (Mallophaga), dragonfly naiads (Odonata), spiders and beetle mites (Arachnida), minute Crustacea, and the internal buds of moss-animals (Bryozoa) and fresh-water sponges (Porifera). Snails (Mollusca) were eaten by 74.62 per cent of the snipe but comprised a small percentage of the total food volume. Seeds of sedges (Cyperaceae), water plantain (Alismaceae), smartweed (Polygonaceae), and bur reed (Sparganiaceae), as well as unidentifiable rootlets in some instances, were taken but formed a small part of the total food eaten. Stones were found in all but four stomachs.

Stomachs of 11 dowitchers were analyzed. Insects constituted 85 to 90 per cent of the diet exclusive of grit. Midge larvae (*Chironomus* sp.) were most important, being taken by 63.63 per cent of the birds. Other animal forms represented included: larvae of biting midges (Ceratopogonidae), dragon-fly naiads, beach fleas (Amphipoda), water fleas (Cladocera), and internal buds of Bryozoa and Porifera. Remains of snails occurred in 9.09 per cent of the dowitchers. Seeds were found but represented a negligible part of the diet. Stones were present in every stomach.

Comparison of food habits of dowitchers and snipe shows that when collected from the same type of habitat there are relatively few differences between these species as to food taken. When collected from their more typical habitats there are certain rather distinct differences in the food habits. Availability and relative abundance of the kinds of animal food found in the type of habitat chosen in each case are the principal factors in determining the variety and amounts of such foods taken. Food preferences which might be indicated by the birds are believed to be of secondary importance.

The lesser yellowlegs food habits study was based upon analyses of 71 stomachs. Insects were again the principal item of diet, but the forms taken were somewhat different from those of snipe and dowitchers. This is probably due to the differences in methods of feeding, which in turn are likely the results of the different morphological characters of the bills and legs of the birds. The true bugs were taken most frequently. Water boatmen (Corixidae) occurred in 70.42 per cent of the yellowlegs. Lygaeidae, Nabidae, Coreidae, and other bugs, in the order named, were of lesser importance. Ants occurred in 42.25 per cent, leaf-hoppers (Homoptera) in 36.62 per cent, larvae of midges in 26.76 per cent, and lantern-flies (Homoptera) in 14.08 per cent of the lesser yellowlegs. Other insects represented were: larvae of water-scavenger beetles, ground beetles (Coleoptera, Carabidae), dragon-fly and damselfly naiads, and caddice-fly (Trichoptera) larvae some of which were still in their stone-

covered cases. Ephyppia of water fleas, ostracods, amphipods, spiders, beetle mites, gemmules of fresh-water sponges, statoblasts of moss-animals, one nematode (Nemathelminthes), and one earthworm (Annelida) were also taken. Snails were eaten by only 5.63 per cent of the yellowlegs. Seeds formed an almost insignificant part of the diet, there being a total of only 52 seeds found in the 71 stomachs. Stones were contained in 78.45 per cent of the stomachs. The occurrences of large numbers of stones were found in several instances to be closely associated with the taking of caddice-fly larvae within their stone-covered larval cases, the stones being taken incidental to the eating of these larvae. Lesser yellowlegs feed not only in shallow water but also on land as is indicated by the kinds of food taken.

The stomachs of three greater yellowlegs were available in the Iowa State College collection and were included merely for whatever value the analyses might have. No conclusions were based upon their examination.

## ON THE RAMAN SPECTRA OF SOME SUGARS<sup>1</sup>

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With the view in mind of obtaining the vibrational frequencies of a number of sugars in the pure state, this preliminary investigation was undertaken. Inasmuch as previous investigators have studied only solutions of the muta-rotating sugars and have therefore obtained a superposition of the vibrational frequencies of their  $\alpha$  and  $\beta$  forms, the present investigation dealt primarily with the Raman spectra of the  $\alpha$  and  $\beta$  forms in the solid state, although equilibrium *d*-glucose solutions were studied too, as well as was crystalline sucrose.

These pure forms are most usually obtained in the form of fine crystalline powders, and therefore a special technique was required to obtain the spectra. After trying the double-spectrograph method of Conrad-Billroth, Kohlrausch, and Reitz, *Z. Electrochem.* 43, 292-293 (1937), and Reitz, *Z. physik. Chem. B.* 46, 181-193 (1940), and abandoning it temporarily because of the complicating factor of the continuum that is always present in the mercury arc in the visible region, recourse was had to ultra-violet excitation. Here, too, many difficulties had to be surmounted, and so a detailed description does not seem to be out of place.

A low-pressure, argon-mercury discharge tube (helical type, 4,400 volts, 0.1 ampere) was used. It was found that the full light from this tube decomposed the sugars, so the light to the low-wave-length side of the Hg 2537 Å line (the exciting line) was removed by a filter of saturated, aqueous succinic acid. This filter solution was circulated through the four-mm. annular space of a fused-quartz filter jacket by means of a midget centrifugal pump. The lamp emitted nearly 80 per cent monochromatic 2537 radiation, so the excitation was by this line only.

Before the light entered the spectrograph, the 2537 line was removed by a mercury-vapor absorption cell. This cell was electrically heated (150°C.), had two fused-quartz windows, and provided a 10-cm. column of mercury vapor. The 2537 line was obliterated completely, and the necessarily long exposures could thus be obtained without fogging the plates.

A Bausch and Lomb medium quartz spectrograph was used. In the region where the Raman spectra lay, the mean dispersion was 120 cm.<sup>-1</sup>/mm. The room housing the spectrograph was thermostated to within 1°C.

The sugar powders were contained in a fused-quartz tube, 6 mm. in internal diameter. This tube was provided with a collimator containing two diaphragms with a 4-mm. aperture. The diaphragms were spaced two inches apart. The length of the sample of powder was about 5 mm. The solutions were contained in a fused-quartz Wood's tube 15 mm. in

<sup>1</sup> Original thesis submitted March 14, 1942. Doctoral thesis number 674.



diameter and 3 inches in active length. The Wood's tube was also provided with a collimator. The powder tube (or the Wood's tube) and the filter jacket were placed axially in the helix, and thus  $90^\circ$  scattering was effected.

The entire excitation unit was housed in a large box provided with a good suction fan. This fan removed the ozone formed from the oxygen in the air by the arc, and the absorption of the ozone was thus not troublesome. The collimator of the powder tube (or Wood's tube) projected from this box, and this ensured that no stray light got into the spectrograph.

The plates used were Eastman Spectroscopic Plates, types 1-0 or 130-0, and were backed. The powder spectrograms were enlarged about sevenfold on high contrast paper and the wave lengths of the Raman lines found by means of the Hartmann formula (enough mercury lines were present to provide standards for measurement). Microphotometric tracings were made of the solution plates with a resulting tenfold enlargement, and the wave lengths of the band edges, shoulders, and maxima were found by means of the Hartmann formula.

The Raman spectra of anhydrous  $\alpha$ - and  $\beta$ -*d*-glucose, equilibrium aqueous *d*-glucose solutions containing 5, 15, and 50 moles of water per mole of glucose, anhydrous  $\beta$ -*d*-mannose, and crystalline sucrose are reported. Thirty-six lines were found for  $\alpha$ -*d*-glucose, 32 for  $\beta$ -*d*-glucose, numerous new bands for the equilibrium *d*-glucose solutions, 73 lines for  $\beta$ -*d*-mannose, and 76 lines for crystalline sucrose.

It was found that only a fair one-to-one correspondence exists among the vibrational frequencies of  $\alpha$ - and  $\beta$ -*d*-glucose. In  $\alpha$ -*d*-glucose, sucrose, and  $\beta$ -*d*-mannose a strong, sharp line was found at approximately  $850\text{ cm}^{-1}$  and is attributed to the breathing frequency of the pyranose ring. Its absence in  $\beta$ -*d*-glucose is thought peculiar but cannot be said to be conclusive until data on many more sugars have been obtained. The most intense lines are those in the C-H region, and in the case of crystalline sucrose, nine strong lines (plus two other weak ones) were found in this region where heretofore only one had been found by previous investigators. Sucrose also exhibits evidence of O-H groups both perturbed and unperturbed by hydrogen bond formation.

In the case of equilibrium *d*-glucose in solution, bands were obtained instead of sharp lines, but it could not be determined conclusively whether or not these bands could be accounted for entirely by the vibrational frequencies of the  $\alpha$  and  $\beta$  forms.

It was concluded that there would be a good chance to use these vibrational frequencies to serve as a means of qualitative (and possibly quantitative) analysis of sugar mixtures, provided these mixtures were not too complicated.



# THE EFFECT OF GENETIC CONSTITUTION AND PROCESSING METHODS ON THE ABILITY OF MAIZE SEED TO GERMINATE IN COLD SOIL<sup>1</sup>

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## PROCESSING METHODS IN RELATION TO GERMINATION UNDER ADVERSE CONDITIONS

When planted in cold, wet soil, some samples of commercial maize seed give poor stands while others under comparable conditions produce good stands. Samples which are susceptible to such adverse conditions may appear from casual inspection to be of good quality and may be as viable and vigorous as resistant samples when subjected to ordinary laboratory germination tests. Samples of the same strain of corn from different producers frequently are widely different in their ability to germinate in cold soil, indicating that genetic constitution of the strains does not account for the difference in performance. The studies being reported were undertaken with the purpose of explaining the anomalous performance of the samples and of finding means of preventing poor stands.

A laboratory cold-test was used to simulate unfavorable field conditions in determining the relative resistance of the various samples to such conditions. The cold-test consisted of planting the seed in wet soil and holding at 45°F. for seven days before moving to a higher temperature to complete germination. Samples which germinated poorly in a cold-test with untreated soil gave nearly perfect stands in a steamed soil cold-test, indicating that a combination of low temperature and soil organisms was responsible for the failure to germinate.

Examination of the kernels with 10 × magnification showed that susceptible samples had a high percentage of kernels with breaks in the pericarp over the germ. The breaks were so inconspicuous that most of them could not be seen with the unaided eye. Data from 50 samples of commercial seed gave a correlation coefficient of  $-.81$  between the percentage of kernels with injuries over the germ and the germination percentage in a cold-test. Highly significant correlations between cold-test germination percentages in the laboratory and field stands were found.

In spite of the fact that the field samples were given a recommended fungicidal dust treatment before planting, significant reductions in stand were associated with pericarp injury. These results indicate that seed injury may be an important cause of poor stands, and stress the need for careful handling of seed corn.

The percentage of kernels with injuries over the germ was related to the processing procedures to which the seed had been subjected.

<sup>1</sup> Original thesis submitted June, 1942. Doctoral thesis number 693.

Shelling was an important source of damage, but additional damage occurred in subsequent operations, particularly when the kernels were dropped against a hard surface. Designs of the processing plants and the procedures used by different producers of seed vary greatly, and the type and degree of injury vary with the different producers. Some consistently produce seed which is relatively free from injury while others rather consistently injure a high percentage of the kernels. This conclusion is based on the average performance of several strains of corn from each of several producers.

A low moisture content of the corn when handled greatly increased the amount of injury. Handling treatments which caused practically no injury at 13-14 per cent moisture, injured 60-80 per cent of kernels with only 8 per cent moisture. Greater brittleness of the pericarp of the drier samples seemed to be responsible for the greater injury. It was suggested that simplification of the processing procedure to eliminate unnecessary dropping of the seed and covering of hard surfaces which the kernels strike with some material to absorb the shock should reduce the amount of injury. Some modification of shelling equipment to reduce injury during shelling should be possible. A factor which seems to be very important and which could be controlled without serious difficulty is the moisture content of the seed during processing. The ability of some companies to produce seed consistently which is relatively free of injuries indicates that the necessary precautions are not impractical.

#### GENETIC CONSTITUTION AND COLD-TEST DAMAGE

In an attempt to determine the importance in cold-test germination of genetic differences between strains, all possible reciprocal single crosses among the inbreds I198, I233, L289, L317, 187-2, Hy, WF9, and 38-11 and the component inbreds were tested. Significant differences between strains were found, but they were erratic in occurrence and seemed to be due to seed condition in the particular samples used rather than to genetic resistance or susceptibility contributed by the parent inbreds. It was concluded that seed produced on inbred plants, because of strong and variable maternal influences, is not favorable material for use in detecting differences in inherent genetic resistance to cold-test conditions. Seed produced on inbred plants is much more sensitive to environmental influences which affect such things as seed infection and seed-coat condition. Seed infection seemed to be the most important factor in giving variable results, but maturity and other factors undoubtedly enter in. Single crosses and inbreds in a steamed-soil cold-test showed about the same reduction in germination as they did in the unsteamed soil test, indicating that seed-borne infection was important. These results with inbreds and single crosses were strikingly different from results with double crosses which showed no reduction in germination in a steamed soil cold-test.

There were significant differences in cold-test germination percentages between reciprocals of single crosses, indicating that some lines are

better seed parents than are others. Inbred 38-11 was an outstanding illustration of a poor seed parent, while L289 and Hy were relatively good ones. The consistently poor performance of crosses involving 38-11 as seed parent is probably accounted for by the tendency of seed of this line to have a cleavage in the pericarp near or over the germ. Reciprocal 3-way crosses illustrate very well the extremes found in seed quality, seed produced on the single cross parent giving much the better germination in cold-tests.

Parental inbreds in nearly all instances germinated less well than the single crosses, suggesting either a relation between vigor and resistance to pathogens responsible for poor germination or a complementary or supplementary action of genes for resistance from the parents. The possible relation between vigor and resistance is discounted by the absence of any correlation between plant height or plant weight and percentage germination in cold-test.

Seed produced on single cross plants is much less sensitive to environmental factors than that produced on inbred plants, and its response to cold-test is much less variable. Since maternal influences may be reduced to a considerable degree by using single crosses as seed parents, 3-way crosses seem to offer possibilities for evaluating the inherent genetic resistance of lines. By using pollen of lines to be tested on a series of tester single crosses, the lines may be compared on the same basis as far as maternal effects are concerned. As a test of this technique Inbreds R4 and I234 were used as pollen parents on six single crosses. Cold-test data for these 3-way crosses indicated that R4 transmitted considerably more resistance to the pathogens responsible for reduced germination than did I234.

# STATICAL EQUILIBRIUM OF SKEW AND SECTOR-SHAPED PLATES<sup>1</sup>

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In this study we are concerned with the solution of the problem of finding the deflection functions from which one may calculate the stresses and the deformations in certain thin elastic plates. The plates considered are of two types, a skew plate or a plate in the form of a parallelogram, and a sector-shaped plate. The method of solution follows the so-called Kirchhoff elementary theory which disregards those internal stresses in planes normal to the plate. The assumptions are made that there is no compressive stress between horizontal layers of the plate, that there is no stretching of the middle surface and that plane sections normal to the middle surface before deformation remain plane and normal to that surface after bending. It is also assumed that the material is isotropic, that the stresses are below the proportional limit, and that the allowable deflections must not exceed one half the thickness of the plate. Although these assumptions might seem at first to be assumptions of convenience which allow the mathematical solution to be simplified, it is a fact that in the elastic range of the material and for small deflections, the Kirchhoff method yields very reliable results. More precisely, this method involves the solution of the fourth order partial differential equation:

$$N \nabla^4 w = p,$$

where  $N$  is the so-called flexural coefficient of stiffness,  $p$  is a function depending on the load, and  $w$  is the deflection function.

The particular skew plate which was studied might be described as the combination of two isosceles right triangles placed in such a way that one pair of legs coincide. Two special cases of this plate are considered.

(1) The plate is supported on all edges so that each edge is free to rotate but is restrained from any deflection while the load function,  $p$ , is taken as constant over the entire plate. (2) The plate is supported in the same manner as before but the load function is taken so that one has only a point load at the center of symmetry. Both of these cases involve the construction of deflection functions which satisfy the plate equation as well as all of the boundary conditions. The particular way in which this was done was to construct two deflection functions for the plate, each function being valid in one of the above right triangles. For the first case these functions are:

$$\begin{aligned} w_1 &= f_1 + \Psi_1, \\ w_2 &= f_2 + \Psi_2, \end{aligned}$$

where:

$$f_1 = \frac{p}{96N} \{ (x + y - a)^4 + 2a(x + y - a)^3 - a^3(x + y - a) \},$$

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$$f_2 = \frac{p}{96N} \{ (x+y)^4 - 2a(x+y)^3 + a^3(x+y) \},$$

$$\begin{aligned} \Psi_1 = & \sum_{n=1,3,5,\dots} \{ A_{n_1} [\sinh \alpha(a-y) \sin \alpha x - \sinh \alpha x \sin \alpha y] + \\ & + B_{n_1} [\sinh \alpha(a-x) \sin \alpha y - \sinh \alpha y \sin \alpha x] + \\ & + C_{n_1} [a-y] \cosh \alpha(a-y) \sin \alpha x - x \cosh \alpha x \sin \alpha y] + \\ & + D_{n_1} [(a-x) \cosh \alpha(a-x) \sin \alpha y - y \cosh \alpha y \sin \alpha x] \}, \end{aligned}$$

$$\begin{aligned} \Psi_2 = & \sum_{n=1,3,5,\dots} \{ A_{n_2} [\sinh \alpha y \sin \alpha x - \sinh \alpha x \sin \alpha y] + \\ & + B_{n_2} [\sinh \alpha(a-x) \sin \alpha y + \sinh \alpha(a+y) \sin \alpha x] + \\ & + C_{n_2} [y \cosh \alpha y \sin \alpha x - x \cosh \alpha x \sin \alpha y] + \\ & + D_{n_2} [(a-x) \cosh \alpha(a-x) \sin \alpha y + (a+y) \cosh \alpha(a+y) \sin \alpha x] \}, \end{aligned}$$

in which  $\alpha = n\pi/a$  and the boundaries of the plate are  $x=0$ ,  $x=a$ ,  $x+y=a$ ,  $x+y=0$ . For the second case the deflection functions are the same as for the first case except that  $f_1 = f_2 = 0$ . All of the arbitrary constants in these functions were evaluated by satisfying the boundary conditions and by matching the functions across the short diagonal where the two right triangles join. By appropriate combinations of the derivatives of these deflection functions one may determine all of the stresses, deformations, moments, and shears at any point in the plate.

The study of a sector-shaped plate involved finding a solution to the plate equation which satisfied all boundary conditions and considered the load function,  $p$ , to be such that only a concentrated load existed at a point  $(r_1, \theta_1)$ . The solution was found for five distinct cases: (1) all the edges are pinned, (2) pinned radial edges and clamped circular edge, (3) pinned radial edges and free circular edge, (4) Navier edge condition all around, (5) pinned radial edges with circular edge at infinity. The deflection functions for all of these cases are of the type

$$w = \sum_{n=1}^{\infty} (A_n r^\alpha + B_n r^{-\alpha} + C_n r^{2+\alpha} + D_n r^{2-\alpha}) \sin \alpha \theta,$$

where  $\alpha = n\pi/\gamma$ , and  $\gamma$  is the angle of the sector ( $0 < \gamma < \pi$ ). The boundaries of the sector are the radial lines  $\theta = 0$ ,  $\theta = \gamma$ , and a circular arc  $r = r_2$ . In cases (4) and (5) a closed form was found for the moment sum,  $M_r + M_\theta$ , and in case (5) a closed form was found for  $M_r$ ,  $M_\theta$ , and  $M_{r\theta}$  as well. These closed forms for case (5) are:

$$M_s = \frac{P(1+\nu)}{4\pi} \log \frac{R^k + R^{-k} - 2 \cos k(\theta_1 + \theta)}{R^k + R^{-k} - 2 \cos k(\theta_1 - \theta)},$$

$$M_r = \frac{M_0}{2} + \frac{1-\nu}{4(1+\nu)} \left( R - \frac{1}{R} \right) \frac{\partial M_0}{\partial R},$$

$$M_\theta = \frac{M_0}{2} - \frac{1-\nu}{4(1+\nu)} \left( R - \frac{1}{R} \right) \frac{\partial M_0}{\partial R},$$

$$M = \frac{1-\nu}{4(1+\nu)} \left( 1 - \frac{1}{R^2} \right) \frac{\partial M_0}{\partial \theta},$$

where

$\nu$  = Poisson's ratio,

$R = r/r_1$ ,

$k = \pi/\gamma$ .

An alternative method of arriving at these closed forms may also be demonstrated by using the conformal mapping method of complex variables in which the sector is mapped on a unit circle with the load point going into the origin of the unit circle. A Green's Function is constructed in this manner and reduced identically to the form written above for the moment sum.

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# THE EMBRYOLOGICAL DEVELOPMENT AND PHYSIOLOGY OF THE ENDOCRINE ORGANS OF THE COMMON FOWL (*GALLUS DOMESTICUS*)<sup>1</sup>

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A series of 420 chick embryos, ranging in age from 12 hours of incubation until hatching, was used for the morphological studies of the developing endocrine organs. Observations were made on the developing hypophysis, thyroid, parathyroid, thymus and adrenal glands, ovaries, and testes by means of serial sagittal, transverse, and frontal sections taken at approximately 12-hour intervals. A series of 240 chick embryos was used for determining the weights and rate of growth of the endocrine organs from the tenth through the twenty-first day of incubation.

## HYPOPHYSIS CEREBRI

At 43 to 48 hours of incubation the hypophysis begins to develop by an ectodermal evagination from the roof of the oral cavity which gives rise to the hypophysial pouch or Rathke's pocket. It exhibits two lateral lobes from which the tuberal processes arise at 60 hours. A definite hypophysial stalk forms at 110 hours, begins to retrogress at 191 hours, and becomes subdivided into clumps of epithelial cells after 228 hours. After 191 hours the hypophysial pouch becomes subdivided, leaving no evidence for a pars intermedia. The pars glandularis is comprised of an anterior and posterior lobe at about 134 hours. The anterior lobe gives rise to a tuberal process on either side which later develops into the pars tuberalis. The infundibular process arises from the infundibulum at approximately 134 hours and later develops lateral outpocketings which become the pars nervosa.

The anterior and posterior lobes of the pars glandularis become cytologically distinct in that the posterior lobe possesses acidophil, basophil, and chromophobe cells, while the anterior lobe contains basophil, chromophobe, and weakly staining acidophils. The cellular elements of the pars glandularis are preceded by undifferentiated cells which take on basophilic tendencies at 191 hours of incubation. Acidophilic cells first appear at 240 hours. The weakly staining acidophilic cells appear in the anterior lobe at 462 hours. A definite connective tissue sheath separates the pars glandularis from the pars nervosa.

Indirect evidence is presented to substantiate the hypothesis that the gonadotropic hormone is produced by the basophil cells; that growth hormone, and thyrotropic hormone are produced by the acidophil cells; that the parathyroid and adrenal cortical cells are associated with activity of the acidophil cells in the posterior lobe, and that the weakly staining

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acidophil cells in the anterior lobe produce intermedin. The percentage weight of the hypophysis decreases from the tenth to the twenty-first day of incubation. There is no significant sex difference between the percentage weights of the hypophyses.

#### GLANDULA THYREOIDEAE

At about 36 hours of incubation the thyroid gland begins development from an unpaired median ventral invagination of the pharyngeal epithelium. The thyroid primordium loses connection with the pharynx at 96 hours and becomes bilobed by 120 hours. Distinct epithelial cell plates appear at 165 hours. Intracellular chromophobic colloid first appears at 240 hours, and the first primary follicle at 260 hours. Chromophilic colloid appears in the follicles at 295 hours. Primary follicular cavities are formed by the secretion and coalescence of the chromophobic colloid. Growth of the follicles is achieved by fusion of the follicular epithelium with cells which have not yet organized into follicular formation and by follicular cell division. A follicular cell lining may secrete either chromophobic or chromophilic colloid; therefore, a follicle contains two types of colloid. There is a progressive increase in the mean follicular diameters from 295 hours until hatching. No significant sex differences occur between the percentage weights of the thyroid glands from the tenth to the twenty-first day of incubation.

#### GLANDULA PARATHYREOIDEAE

The parathyroid primordium evaginates with that of the thyroid from the floor of the pharynx, migrates posteriorly, and becomes separated from the thyroid primordium as a lateral lobe at 148 hours. This becomes the anterior lobe of the parathyroid and at 165 hours gives rise to the posterior lobe. The parathyroid epithelial cell cords grow peripherally from a central, crescent-shaped epithelial cell cord. Three types of cells, based on cellular structure and staining characteristics, are demonstrable in the parathyroid glands at 400 hours of incubation: a clear nongranular type; a lightly acidophilic, finely granular type; a coarsely granular type, which stains intensely with acid dyes. Indirect evidence is presented which indicates that the small, lightly acidophilic staining cells in the parathyroid glands are responsible for the active principle initiating calcification of the embryonic skeleton.

#### THYMUS

After 120 hours the double origin of the thymus can be observed. The large portion or thymus III is derived from the ventral and lateral wall of the third visceral pouch. Thymus IV, a smaller portion than thymus III, is derived from the dorsal wall of the intermediate part of the fourth visceral pouch and eventually fuses with thymus III. The first lymphocytes migrate into the thymic tissue from the surrounding mesenchyme, while the small thymic cells arise from cellular division of the large lymphocytes. Connective tissue ingrowth from the primitive capsule, and growth and

increase in the number of the epithelial cells produce the primary lobules at 213 hours. After the capsule forms, the lymphocytes migrate into the thymic tissue along the interlobular septa. At 357 hours a cortical and medullary zone can be definitely separated in the thymic tissue. The medulla develops from the epithelial syncytium of the thymic primordium. Hassall's corpuscles develop from the medullary epithelial cells. No evidence was obtained to indicate that thymic development is dependent on the function of other endocrine organs. The percentage weights of the developing thymus from the tenth to the twenty-first day are consistently less in the female as compared with the male; however, this difference is not significant.

#### GLANDULA ADRENALIS

The cortical cell primordia of the adrenal glands appear between 90 and 96 hours as groups of cells derived from the coelomic epithelium. Sympathetic cells derived from the primary sympathetic trunks have migrated between the cortical cells in the 134-hour embryo. Masses of sympathetic cells appear along the dorso-medial surfaces of the adrenal glands at 148 hours. These sympathetic cell masses consist of two types of cells, namely ganglionic and nonganglionic. It is believed that these cells arise from the secondary or definitive sympathetic trunks. Both of these cell types migrate into the adrenal tissue at 165 hours. Indirect evidence is presented to show that the ganglionic cells may transform into chromaffin cells, and also that the nonganglionic cells may give rise to the chromaffin cells. The chromaffin cords arrange themselves within the gland so that some portion is next to a venous sinusoid. The mean adrenal weights and percentage weights from the tenth to the twenty-first day of the incubation period present no significant sex differences. There is a rather gradual decrease in the percentage weights in both sexes from the eleventh to the twenty-first day of incubation.

#### INDIFFERENT GONAD

A single layer germinal epithelium covers the embryonic gonad from 90 to 96 hours. At this time the left gonad is larger than the right. At 96 hours the left gonad contains approximately 70 per cent, while the right contains 30 per cent, of the total germ cells present at this time. The sexual cords of first proliferation become well developed between 134 and 165 hours of incubation.

#### OVARIUM

The primordial germ cells begin mitotic division at 191 hours, and reach a peak of proliferation between 213 and 228 hours. Cortical cords, or the cords of second proliferation are clearly demonstrable by 213 hours in the left ovary. The germinal epithelium covering the right ovary is reduced to a single layer of cuboidal cells at 228 hours, while it is not until 284 hours that the germinal epithelium covering the left ovary is reduced to a single layer of cells. The mean weights of the left ovary increase from

the tenth until the eighteenth day of incubation when they begin to plateau. The percentage weight of the right ovary decreases from the tenth until the twenty-first day. The percentage weight of the left ovary decreases slowly from the thirteenth day until hatching.

#### TESTIS

The seminiferous cords are discernible at 165 hours of incubation. Seminiferous cords after 177 hours comprise most of the male gonads because the germinal epithelium has been reduced to a single layer of cuboidal epithelium. The primordial germ cells are first observed in cellular division at 206 hours. The intertubular tissue begins to increase at 213 hours. Interstitial cells differentiated from the intertubular stroma first appear at 272 hours. From 307 hours until hatching discontinuous lumina appear in the seminiferous cords. The mean testes weights increase progressively from the tenth to the twenty-first day of incubation. There is no significant difference between the mean weight of the testes and the left ovary from the tenth to the twenty-first day of incubation.

# THE ABSORPTION SPECTRA OF SOLIDS<sup>1</sup>

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This research was undertaken to study further some of the forces existent in the solid state and to provide experimental data for the checking of theoretical work such as the prediction of magnetic susceptibilities and specific heats from the energy states of the molecule.

A grating spectrophotometer embodying a satisfactory compromise between high dispersion and speed was constructed for use in the determination of the absorption spectra of solids. The instrument may be converted into a stigmatic grating spectrograph covering the range from 1,850 to 12,000 angstroms with an almost normal dispersion of 11 angstroms per millimeter; the range of the spectrophotometer is limited to from 3,000 to 10,000 angstroms by the spectral sensitivity of the photoelectric surface. The spectral regions isolated varied from 1 to 10 angstroms. The overall linearity of response of the spectrophotometer was tested by determining the transmission at various wave lengths of two calibrated filters furnished by the Bureau of Standards.

Praseodymium was molecularly mixed with other rare earths to permit a study of the ion in a number of crystal modifications. The stability of the individual lattice of the rare earth sesquioxides is dependent upon the atomic number of the cation and the temperature of preparation. The slow rate of conversion from one crystal form to another makes the temperature at which the oxide is formed the most important factor in the preparation of a given crystal modification rather than the final temperature to which it is heated. The difficulties encountered in the preparation of pure forms of the various crystal modifications of the rare earth oxides suggest that earlier methods for the preparation of the various polymorphic forms are not reliable and samples should be checked with an X-ray analysis. It is probable that some of the different values reported for magnetic susceptibilities are due to variations in the samples used.

Europium oxide was prepared in three crystal modifications, a low temperature form which has been satisfactorily indexed on the tetragonal system and the cubic and pseudotrigonal forms which have been previously reported by other investigators. The X-ray data and unit cell dimensions have been given for the tetragonal and cubic modifications. The pseudotrigonal modification was not obtained in the pure form, and no attempt was made to index the crystal, since it appeared to be of low symmetry. Lanthanum sesquioxide was prepared in the hexagonal form and in two unidentifiable crystal modifications which have been designated as X and B. The X-ray data are given for the hexagonal and X form of lanthanum sesquioxide. Procedures are given for the preparation of the

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various crystal modifications of lanthanum and europium oxides.

The absorption spectrum of praseodymium sesquioxide contained in the tetragonal lattice of europium oxide as well as in the hexagonal and X forms of lanthanum oxide was obtained at 78° and 300° Kelvin. The absorption spectra of the oxides were determined by photographic means since the electromagnetic method of voltage control proved inadequate for the operation of the spectrophotometer at the level of sensitivity required by the high optical density of the samples. Electronic levels at 0 and 99 wave numbers were found for the praseodymium oxide in these three types of crystal structure. The two low-lying states were established by the repetition of their spacing in several multiplets and by the temperature dependence of these lines. Lines arising from the two states and terminating in common upper levels are separated by an interval equal to that separating the two lower levels. Those transitions arising from the lowest level show a marked increase in intensity as the temperature is lowered because of the increase in the population of this level, and those arising from the higher level increase in intensity as the population of the level increases with increasing temperatures. The intensity cannot be relied upon with certainty to indicate the lines of electronic origin since it is possible for a coupled electronic and vibrational line to be intense under favorable conditions.

A value of 108 wave numbers was obtained for the mean separation of the two levels at a temperature of 300° K; this shift from 99  $\text{cm}^{-1}$  at 78° K was produced by the change in the effective fields on the electrons as the crystal expanded on warming. In general, the lines at room temperatures are shifted about ten wave numbers to the blue from the corresponding lines at the temperature of liquid nitrogen; the magnitude of this temperature shift varies with the relative amounts, the levels of origin and of terminus are influenced by the change of fields. In addition to the shift in the positions of the lines, some of them were observed to become more diffuse at higher temperatures; the thermal vibrations produce fields of varying intensity, and the diffuse lines observed are a summation of many sharp transitions to a fluctuating level.

The spectra for the three crystal modifications of praseodymium sesquioxide observed are shifted several hundred wave numbers to the red from comparable multiplets of other praseodymium compounds; this is probably a result of the more intense crystal fields. The spectra of the oxide consist of a red multiplet at 6,000 angstroms corresponding to the transition  $^3\text{H}_4$  to  $^1\text{I}_6$ . The three very strong multiplets occurring in the blue region arise from transitions from a  $^3\text{H}_4$  to a  $^3\text{P}_0$ ,  $^3\text{P}_1$ , and  $^3\text{P}_2$ . The strong lines observed overlie a general absorption which becomes increasingly strong with shorter wave lengths.

Although theory predicts that the basic  $^3\text{H}_4$  level of praseodymium will be split into four components by crystal fields of cubic symmetry and into nine components with fields of low symmetry, definite evidence was obtained for the existence of only two low-lying levels. It is probable that the other levels are higher, since the fields are stronger and the splitting

of the levels is greater. The population in these higher levels would be negligible at the temperatures of the measurements, and no transitions arising from these levels would be expected.

An indication of the relative symmetry of the electrical fields about the rare earth ion in the various crystal modifications was obtained from a comparison of their spectra. Since the spectrum observed is particularly sensitive to the symmetry about the metal ion, the absorption spectrum should prove more satisfactory in the selection of a space group than the indirect method provided by X-ray data.

# METALATION OF SULFUR-CONTAINING ORGANIC COMPOUNDS<sup>1</sup>

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Sulfur-containing organic compounds have become of increasing interest in recent years because of their physiological properties and because of their significance to theoretical and practical organic chemistry. The metalation of sulfur compounds appeared to offer the possibility that some unusual orientations would be obtained in view of earlier work in this field. For example, dibenzothiophene was metalated by phenylcalcium iodide to yield, on carbonation, 3-dibenzothiophenecarboxylic acid, whereas organolithium compounds metalated dibenzothiophene in the 4-position.<sup>2</sup> Furthermore, methyl phenyl sulfide gave a lateral metalation product with *n*-butyllithium,<sup>3</sup> but the corresponding oxygen compound, anisole, yielded a nuclear metalation product under the same conditions.<sup>4</sup>

A review has been made of the reactions of sulfides, disulfides, sulf-oxides, and sulfones with sodium, sodamide, mercuric salts, and organo-metallic compounds.

A series of methyl aryl sulfides has been metalated by *n*-butyllithium in diethyl ether. In each case the metalation product was identified, subsequent to carbonation, as an arylmercaptoacetic acid. Therefore, lateral metalation occurred in each case. No nuclear metalation products were isolated under these conditions. The methyl sulfides investigated had the general formula RSCH<sub>3</sub>, where R was *p*-tolyl, *p*-chlorophenyl, *p*-dimethylaminophenyl,  $\alpha$ -naphthyl, and  $\beta$ -naphthyl. The yield of *p*-tolylmercaptoacetic acid in the case of methyl *p*-tolyl sulfide was 38.2 per cent after 16 hours of refluxing. With *p*-chlorophenyl methyl sulfide 5.75 per cent of *p*-chlorophenylmercaptoacetic acid was obtained after 5 hours at 34°. Two experiments with *p*-dimethylaminophenyl methyl sulfide gave 22.4 per cent and 15.2 per cent of *p*-dimethylaminophenylmercaptoacetic acid; m. p. 85–86°. A 35.4 per cent yield of  $\alpha$ -naphthylmercaptoacetic acid was obtained from methyl  $\alpha$ -naphthyl sulfide after 5 hours in ether, whereas methyl  $\beta$ -naphthyl sulfide gave only an 11.7 per cent yield of the corresponding acetic acid after 20 hours of refluxing in the same solvent.

When ethyl phenyl sulfide was refluxed 15 hours with *n*-butyllithium in ether, and then carbonated, *o*-ethylmercaptobenzoic acid resulted (7.7, 8.4 per cent). Similarly, phenyl *n*-propyl sulfide, isopropyl phenyl sulfide, and *n*-butyl phenyl sulfide were metalated by *n*-butyllithium to yield, after

<sup>1</sup> Original thesis submitted July 17, 1941. Doctoral thesis number 640.

<sup>2</sup> Gilman and Jacoby, *J. Org. Chem.*, **3**, 108 (1938); Gilman, Jacoby, and Pacevitz, *ibid.*, **3**, 120 (1938).

<sup>3</sup> Gilman and Webb, *J. Am. Chem. Soc.*, **62**, 987 (1940).

<sup>4</sup> Gilman and Bebb, *ibid.*, **61**, 109 (1939).

carbonation, *o*-(*n*-propylmercapto) benzoic acid (6.9 per cent), *o*-isopropylmercaptobenzoic acid, m. p. 116–117° (11.4, 11.0 per cent), and *o*-(*n*-butylmercapto) benzoic acid (10.0, 7.38, and 6.5 per cent), respectively. A similar reaction with cyclohexyl phenyl sulfide gave an acid (8.5 per cent) believed to be *o*-cyclohexylmercaptobenzoic acid, m. p. 80–81°. The identification of this compound was not completed. Each of these reactions, with the exception of the one with isopropyl phenyl sulfide, gave a small quantity of benzoic acid, produced by cleavage of the phenyl-sulfur linkage. The reactions with isopropyl phenyl sulfide and *n*-butyl phenyl sulfide yielded, in addition to the acids mentioned above, small quantities of unidentified sulfur acids. *n*-Butyl mercaptan was isolated (in the form of its lead salt) from the reaction of *n*-butyllithium with *n*-butyl phenyl sulfide. No mercaptans were found in any of the other reactions. The behavior of the methyl aryl sulfides is sharply differentiated from that of the alkyl phenyl sulfides having an alkyl group larger than methyl. In general, the lateral metalations proceeded to a greater extent than the nuclear metalations, and cleavage to yield benzoic acid was not observed. Ethyl  $\beta$ -naphthyl sulfide was metalated by *n*-butyllithium, but the acid isolated was not identified. Its high melting point, however, precluded the possibility of a lateral metalation.

Methyl phenyl sulfide and ethyl phenyl sulfide were not metalated by phenylcalcium iodide in ether solution. Methyl phenyl sulfide was not metalated by this reagent at 150–160° in the absence of a solvent.

Three different positions in the methyl phenyl sulfide molecule were substituted by the use of different metalating agents. Mercuric acetate heated on a steam bath with excess methyl phenyl sulfide gave 36.6 per cent of *p*-acetoxymercuriphenyl methyl sulfide; m. p. 184°. The structure of the mercurial was proved by converting it to the corresponding bromomercury compound which was compared with an authentic specimen of *p*-methylmercaptophenylmercuric bromide (m. p. 268–269°), prepared from the corresponding Grignard reagent and mercuric bromide. Methylolithium and phenyllithium in ether, *n*-butyllithium in petroleum ether (b. p. 28–30°), and phenylsodium in benzene reacted with methyl phenyl sulfide to give phenylmercaptoacetic acid after carbonation. However, when *n*-butylmagnesium bromide and methyl phenyl sulfide were heated together for 5 hours at 150–155°, the product, on carbonation, was *o*-methylmercaptobenzoic acid (0.2 per cent). A corresponding high temperature reaction with *n*-butyllithium and methyl phenyl sulfide gave 21.2 per cent of phenylmercaptoacetic acid. The above results indicate that it is the metalating agent and not the temperature or solvent which governs the position of substitution in methyl phenyl sulfide.

Methyl phenyl sulfide with sodium in ether was cleaved to yield 20.9 per cent of thiophenol and 3.45 per cent of phenylmercaptoacetic acid, subsequent to carbonation and hydrolysis. Scarcely any cleavage occurred when the same reaction was performed in benzene. Lithium cleaved *n*-butyl phenyl sulfide in ether to yield benzoic acid (11.9 per cent), thiophenol (20.5 per cent), and *o*-(*n*-butylmercapto) benzoic acid

(0.24 per cent). No *n*-butyl mercaptan was isolated.

Thiophenol and diphenyl disulfide were metalated by *n*-butyllithium to give the same product subsequent to carbonation, *o,o'*-dicarboxydiphenyl disulfide. From the reaction with diphenyl disulfide, 31.4 per cent of *n*-butyl phenyl sulfide was obtained.

Studies of the relative rates of metalation of methyl phenyl sulfide and methyl phenyl ether indicate that the sulfide is metalated slightly more readily than the oxygen compound by *n*-butyllithium in ether.

*p*-Bromophenyl methyl sulfide did not form an organolithium compound when the usual procedure was followed. The main reaction of *n*-butyllithium with *p*-bromophenyl methyl sulfide was halogen-metal interconversion. Hence the organolithium compound is readily available by this method. With methyllithium, *p*-bromophenyl methyl sulfide gave mainly coupling. Interconversion, however, occurred to a slight extent.

Methyl phenyl sulfone was metalated by *n*-butyllithium to yield benzenesulfonylactic acid (47.0 per cent) subsequent to carbonation. Ethyl phenyl sulfone reacted vigorously with ethylmagnesium bromide. The carboxylic acid fraction isolated on carbonation was a liquid which was not identified. A crystalline compound, soluble in potassium hydroxide solution, but insoluble in sodium carbonate solution was isolated from this reaction, but not identified. Similar results were obtained with *n*-butyllithium, but no crystalline substance was found. Both diphenyl sulfone and dibenzothiophene 5-dioxide were metalated by *n*-butyllithium, as evidenced by the isolation of carboxylic acids. These were gums which were not crystallized or identified.

Methyl phenyl selenide was cleaved by *n*-butyllithium in ether solution to yield, on carbonation, 28.4 per cent of benzoic acid in 19 hours, and 21.0 per cent of the same acid in 4 hours. *n*-Butyl methyl selenide was an additional cleavage product. *n*-Amylsodium in petroleum ether (b. p. 28–38°) cleaved methyl phenyl selenide to the extent of 25.0 per cent in 4 hours at room temperature.

## SOME FACTORS AFFECTING THE GERMICIDAL EFFICIENCY OF CHLORAMINES<sup>1</sup>

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Chlorine is employed almost universally as a sterilizing agent to render water safe for drinking purposes. Undesirable tastes and odors have frequently been produced as a result of chlorination of water and it has been observed that the addition of ammonia before chlorination has on many occasions prevented such objectionable defects. The ammonia is added either as a salt, the hydroxide, or the gas.

Numerous conflicting results as to the relative germicidal efficiency of chlorine and chloramines have been reported in recent years and it therefore seemed desirable to make a study of the germicidal activities of these compounds under controlled conditions with respect to reaction (pH), concentration, and temperature.

A technique has been developed for maintaining desired reactions (pH) of solutions of chlorine and chloramines for determining relative germicidal efficiency.

Bacterial spores were considered particularly suitable for this study since it is possible thereby to employ wider ranges of reaction (pH), temperature, and concentration than is feasible with vegetative cells. The test organism (*Bacillus metiens*) has previously been employed in studies on disinfection with alkalies, chloramine-T, and calcium hypochlorite.

Spore suspensions prepared in Butterfield's formula "C" water and stored at 10°C. showed no appreciable change in resistance to chlorine and chloramine solutions for a period of more than nine months.

The influence of reaction (pH) on the germicidal efficiency of chlorine and chloramines was ascertained by determining the time required to kill 99 per cent of the exposed *B. metiens* spores at pH 5, 6, 7, 8, 9, and 10 in buffered solutions. The following results were observed:

a. With initial concentrations of 22 to 24 ppm. available chlorine as hypochlorite, the killing times were very short, namely, 2.1 to 3.0 minutes in the range pH 5 to pH 7. At pH 8 the killing time rose to 7.6 minutes, at pH 9 to 58 minutes and at pH 10 it increased very markedly to 570 minutes.

b. When 25 ppm. available chlorine were added to 0.5 and 2 ppm. ammonia in buffered solutions at 20°C., there was a drop in chlorine concentration corresponding to approximately 7 times the ammonia added, due to the oxidation of ammonia, the residual chlorine existing as hypochlorite. Except for the fact that the killing times were increased because of the lower residual chlorine, the effect of reaction was similar to that reported above for hypochlorite.

<sup>1</sup> Original thesis submitted July 15, 1940. Doctoral thesis number 582.



c. The effect of reaction on the germicidal efficiency of chloramines (about 25 ppm. available chlorine) was quite different from that observed for hypochlorites. Thus, when 25 ppm. available chlorine was added to 6 ppm. ammonia (the theoretical ratio of chlorine to ammonia for chloramine) killing times of 83 to 89 minutes were observed at pH 8 to 6; at a more acid reaction (pH 5) the killing time rose to 168 minutes, and similarly, at more alkaline reactions, pH 9 and 10, the killing times increased to 182 and 186 minutes, respectively.

With a greater ammonia concentration (18 ppm.) the killing time for approximately 25 ppm. available chlorine at pH 7 was about the same as when 6 ppm. ammonia had been employed, namely, 84 minutes. At a slightly more acid reaction (pH 6) the killing time dropped to 59 minutes, but at a still more acid reaction (pH 5) the killing time rose to 99 minutes. In the alkaline solutions, pH 8, 9, and 10, the killing times rose very rapidly to 107, 263, and 456 minutes, respectively. It appears, therefore, that there is an optimum reaction for germicidal efficiency of ammonia-chlorine mixtures and that the killing time increases in more acid or alkaline solutions.

d. Chloramine was found to be more efficient as a germicide than hypochlorite in solutions more alkaline than about pH 9.4, but the hypochlorites were markedly more efficient than chloramine (6 ppm. ammonia plus 25 ppm. available chlorine) in acid solutions. Plots of the killing times for approximately 25 ppm. available chlorine as chloramine or as hypochlorite against reaction (pH) cross at pH 9.4. At the more alkaline reaction of pH 10, chloramine showed a killing time of 186 minutes as compared with 570 minutes for the hypochlorite; at a more acid reaction, as for example pH 8, killing times for chloramine and hypochlorite were 83 minutes and 7.6 minutes, respectively.

e. When killing times were plotted against reaction (pH) the curve for chloramine (6 ppm. ammonia plus 25 ppm. available chlorine) crossed that for chloramine with excess ammonia (18 ppm. ammonia plus 25 ppm. available chlorine) at about pH 7.3. Thus, excess ammonia resulted in little change in killing time over what was observed for chloramine near neutrality, a shorter killing time at acid reactions (pH 6 and 5) and an increased killing time at alkaline reactions (pH 8, 9, and 10).

The effect of concentration on the germicidal efficiency of chlorine (hypochlorite) and chloramine (ratio of available chlorine to ammonia = 4.2/1) was observed in buffered solutions at pH 10 and 20°C. with the following results:

a. When the logarithms of the initial concentrations of chlorine as hypochlorite were plotted against the logarithms of the killing times, the points fell on a straight line, the equation for which was:

$$\log y = (-0.860) \log x + 3.936,$$

where  $y$  is the killing time in minutes and  $x$  is the initial concentration of available chlorine in ppm. In general, it may be said that when the chlorine concentration was doubled the killing time was reduced by 40 per cent.

b. Plotting the logarithms of the initial available chlorine concentration (as chloramine) against the logarithms of the killing times gave a slightly curved line. As the concentration of chloramine (expressed as available chlorine) increased, the relative decrease in killing time became progressively less.

The effect of temperature on the germicidal efficiency of chlorine (hypochlorite) and chloramine (6 ppm. ammonia plus 25 ppm. available chlorine) was determined by observing the killing times of solutions containing approximately 25 ppm. available chlorine at pH 10 for temperatures of 20°C., 30°C., 40°C., and 50°C. with results indicated below.

a. For a stipulated concentration, a plot of the logarithms of the killing times against the logarithms of the temperatures approximated a straight line, the equation for which is:

$$\log y = (-0.370) \log x + 2.334,$$

where  $y$  is the temperature in degrees centigrade and  $x$  is the killing time in minutes. The killing time was shortened by about 60 per cent for each 10°C. rise in temperature.

b. For a given concentration of chloramine, a plot of the logarithms of the killing times against the logarithms of the temperatures yielded a straight line, the equation for which is:

$$\log y = (-0.222) \log x + 1.883,$$

where  $y$  is the temperature in degrees centigrade and  $x$  is the killing time in minutes. A rise of 10° C. induced a decrease in the killing time of approximately 75 per cent.

# MEAT IN NUTRITION XXI. DISTRIBUTION AND PARTITION OF FATS IN CERTAIN TISSUES OF RATS FED A DIET CONTAINING DRIED AUTOCLAVED PORK MUSCLE<sup>1</sup>

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Workers in the Nutrition Laboratory of the Foods and Nutrition Department at the Iowa State College have found that the feeding of a supposedly adequate diet containing dried autoclaved pork muscle to rats consistently produces a pregnancy disorder at parturition in approximately one-third of the animals maintained on the ration. A fatty yellow liver is a characteristic finding at necropsy.

The present investigation was undertaken to determine whether any derangement in the metabolism of fat occurs as a sequence of feeding the pork diet to rats. The total quantity of fat present and the relative concentrations of various lipid fractions in the liver and blood were used as indices of measurement. The relationship of the fatty liver to the pregnancy disease was also studied.

In analyses relating to fatty constituents in the liver, data obtained from pregnant females fed the pork-containing diet were compared with those derived from groups of normal animals maintained on the diet fed the stock colony of the laboratory. Virgin animals reared on each diet were also studied to determine the effect of pregnancy *per se*.

Each pregnant animal was allowed to rear the first litter. On the 21.5 day of the second pregnancy, after a 10-hour starvation period, the liver was removed for analysis. The virgins were killed when they were approximately the same age as the gravid rats.

In one series of experiments, the quantity of total fat in the liver of the animal was determined gravimetrically from the alcohol-ether extract; in a second series, the oxidative procedure of Bloor was used to estimate the concentrations of total fatty acids, phospholipids, and total and free cholesterol in the alcohol-ether extract of the liver. Percentages were expressed on the basis of dry liver weight. The iodine numbers of the phospholipid fatty acids and of the acetone-soluble fatty acids in the liver lipids were also determined.

The first analysis dealt with the effect of the feeding of the pork diet on the weight of the liver, and on the relative amounts of moisture and fat present. The following facts were demonstrated:

1. Feeding the pork diet to virgin rats produced no change in the weight of the liver or in its moisture content. However, the quantity of total lipids present increased (25.0 and 20.6 per cent in the livers of the experimental and control virgins, respectively).

2. Pregnancy *per se* in the normal animal brought about a definite

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<sup>1</sup>Original thesis submitted June, 1942. Doctor's thesis number 698.

increase in liver size was no concomitant change in the moisture or lipid content of the organ.

3. In the gravid pork-fed animal, the expected enlargement of the liver occurred. However, the diet produced a dehydration of tissue and a deposition of fat greater than that noted in the virgin rat.

4. The feeding of the pork ration to gravid rats caused a dehydration of liver tissue (the normal value, 70.5 per cent, fell to 65.5) and a deposition of fat in the organ greater than that occurring in the normal pregnant animals (40.1 *vs.* 22.0 per cent).

5. The development of the toxemic condition induced no further change in the quantity of either the moisture or the fat present in the liver of the pork-fed rat.

In the second analysis, the relative concentrations of the various lipid components of the alcohol-ether extract of the livers of the experimental and control rats were determined. The feeding of the pork-containing diet to the pregnant rat produced a definite accumulation of fatty acids in the liver, that was largely composed of neutral fat. The average percentage of total fatty acids in the livers of the pork-fed rats was 29.2; in the control animals, 12.1. No significant change was noted in either the quantity of phospholipid or of total cholesterol present. However, a significant reduction in the quantity of free cholesterol, 0.15 per cent, was accompanied by a significant increase, 0.14 per cent, in the amount of ester cholesterol. Pregnancy disease did not change the amounts of the various lipid fractions in the liver from those characteristic of the liver fat in the nontoxic group of animals fed the pork ration. The phospholipid fatty acid iodine numbers were approximately the same in the experimental and control groups (153 and 149, respectively). The iodine numbers of the acetone-soluble fatty acids seemed to indicate a greater saturation of the fat in the livers of the pork-fed group than in those of the control group (128 *vs.* 141).

The general picture suggests a disturbance in fat metabolism. The increase in neutral fat and cholesterol esters accompanied by the reduction in free cholesterol is indicative of a degenerating and inactive tissue. The drop in the acetone-soluble fatty acid iodine number may be significant also.

In the third analysis, the concentrations of total fatty acids, phospholipids, and total cholesterol in the plasma of pregnant control animals were compared with those in the plasma of gravid rats receiving the pork diet. In the case of each fraction studied, it was found that the average value per 100 ml. of plasma for the control group was twice the corresponding value for the experimental group, *i. e.*, 448 *vs.* 214 mg. total fatty acids, 178 *vs.* 87 mg. phospholipids, and 86 *vs.* 49 mg. total cholesterol. The decreased concentrations of all lipid constituents undoubtedly bear a relation to the increase in liver fat. The low plasma values for cholesterol and phospholipid may be interpreted as indicative of hepatic damage.

The fourth analysis of the investigation related to the lipids in the livers of a group of toxemic females which were fed the basal pork diet

enriched with various dietary supplements. Approximately one-half of the livers analyzed for total fat in this group of animals were normal with respect to fat. The liver lipids were fractionated in a few instances. One animal that had received lipocaic in its diet developed the toxemia even though all the lipid components were normal.

Two general conclusions may be drawn from the data reported in the present investigation. They may be stated as follows:

1. Fat metabolism is altered in the pregnant rat following the feeding of a diet containing dried autoclaved pork muscle.

2. However, the development of a fatty liver is not a basic cause of the pregnancy disease that so frequently occurs in rats maintained on this ration.

# THE EFFECT OF REDUCTION ON THE ROTATORY POWER OF SOME FURAN COMPOUNDS<sup>1</sup>

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The furyl group and its reduction products form a series of three radicals covering a wide range of electronegativity. The furyl group is quite electronegative, the tetrahydrofuryl group is less electronegative, and the *n*-butyl group is electropositive. The stepwise reduction of an optically active compound containing the furyl group may, therefore, be used as a means of studying the relation between the rotatory power of a molecule and the electronegativity of the radicals attached to the asymmetric carbon atom. If the E.S.A.'s (electron-sharing abilities) of the radicals, as determined by the dissociation constants of their amines or acids, are taken as the group constants, the product-of-asymmetry theory predicts that if one radical of an active molecule is varied, the rotation of the compound will not change sign as long as the E.S.A. of the radical does not become less than or greater than that of any other radical present.

Diethyl furfurylidenemalonate was prepared by condensing diethyl malonate and furfural by means of an excess of acetic anhydride. The proper Grignard reagent was prepared and added to the unsaturated ester, and the resulting substituted malonic ester was hydrolyzed and decarboxylated. In this way  $\beta$ -( $\alpha$ -furyl)-valeric,  $\beta$ -( $\alpha$ -furyl)-caproic, and  $\beta$ -( $\alpha$ -furyl)- $\beta$ -phenylpropionic acids were prepared. Crystallization of the quinine salts followed by hydrolysis yielded *d*- $\beta$ -( $\alpha$ -furyl)-valeric acid  $[\alpha]_D^{25} + 9.94^\circ$  and *d*- $\beta$ -( $\alpha$ -furyl)-caproic acid  $[\alpha]_D^{27} + 4.57^\circ$ . Attempts to complete the resolution by crystallization of the more soluble salt or by crystallization of the strychnine, brucine, cinchonine, *d*- $\beta$ -naphthol phenylaminomethane, or *d*- $\alpha$ -phenylethylamine salts failed. *d*- $\beta$ -( $\alpha$ -Furyl)- $\beta$ -phenylpropionic acid  $[\alpha]_D^{25} + 69.1$  (ethanol,  $c = 1.3$ ), m. p.  $85^\circ$ , was obtained from the *l*- $\alpha$ -phenylethylamine salt. The *l*-isomer  $[\alpha]_D^{32} - 56.3$  (ethanol,  $c = 5.0$ ), m. p.  $85 - 87^\circ$ , in less pure form was obtained from *d*- $\alpha$ -phenylethylamine salt.

Fractions of these active acids were shaken with hydrogen and platinum oxide in alcoholic solution until the calculated amount of hydrogen had been taken up. The reduced acids were treated with liquid hydrogen iodide at room temperature for several days and were then shaken with zinc and hydrochloric acid to give the corresponding  $\beta$ -substituted  $\beta$ -(*n*-butyl)-propionic acids. Some racemization occurred during the distillation of the acids containing the furyl group as well as during one or more of the steps in the reduction. The rotation data are summarized in the table, and the dispersion ratios  $\alpha_{4358}/\alpha_{5461}$ , of the different acids are given. These ratios indicate that the rotatory dispersion curves are about normal except for  $\beta$ -( $\alpha$ -tetrahydrofuryl)-valeric and  $\beta$ -( $\alpha$ -tetrahydrofuryl)-caproic acids.

<sup>1</sup> Original thesis submitted December 18, 1941. Doctoral thesis number 670.



TABLE 1  
 ROTATORY POWER OF  $\beta$ -( $\alpha$ -FURYL)-PROPIONIC ACIDS AND THEIR REDUCTION PRODUCTS

ACIDS	$[\alpha]_D^*$	$[\alpha]_D$ (BENZENE)	$[\alpha]_D$ (ETHANOL)	DIS- PER- SION RATIO
$\beta$ -( $\alpha$ -Furyl)-valeric .....	$-3.17^\circ$	$-3.48^\circ$	.....	1.83*
$\beta$ -( $\alpha$ -Furyl)-caproic .....	$+2.54$	$+4.00^\circ$	.....	1.86*
$\beta$ -( $\alpha$ -Furyl)- $\beta$ -phenylpropionic .....	.....	$+85.4^\circ$	$69.1^\circ$	1.70†
$\beta$ -( $\alpha$ -Tetrahydrofuryl)-valeric .....	$+0.24^\circ$	.....	.....	2.19
$\beta$ -( $\alpha$ -Tetrahydrofuryl)-caproic .....	$-0.48^\circ$	.....	.....	2.34
$\beta$ -( $\alpha$ -Tetrahydrofuryl)- $\beta$ -phenylpropionic ..	.....	$+35.9^\circ$	.....	1.76
$\beta$ -( <i>n</i> -Butyl)-valeric .....	.....	$-0.70^\circ$	.....	.....
$\beta$ -( <i>n</i> -Butyl)-caproic .....	.....	$+0.28^\circ$	.....	.....
$\beta$ -( <i>n</i> -Butyl)- $\beta$ -phenylpropionic .....	.....	$+23.1^\circ$ †	.....	1.64

\* Homogeneous.

† This value has been calculated. It is the rotation that would have been obtained if the acid of maximum rotatory power had been used in the reductions.

‡ Ethanol.

Since the E.S.A.'s of the furyl and tetrahydrofuryl groups are intermediate between those of H and  $\text{CH}_2\text{COOH}$ , there should be no change of sign by the first step of the reduction of *l*- $\beta$ -( $\alpha$ -furyl)-valeric acid. Experimentally this reduction yielded an acid of low positive rotation. This rotation, however, may not be that of the first asymmetric carbon. Asymmetric addition of hydrogen may have produced a second active center strongly enough positive to change the rotation of the entire molecule. In reducing the tetrahydrofuryl group to the *n*-butyl group the E.S.A. becomes less than that of hydrogen, and the sign should be opposite to that of the unreduced acid. The rotation of  $\beta$ -(*n*-butyl)-valeric acid was found to have the same sign as the unreduced acid. The changes of sign that occurred on the reduction of *d*- $\beta$ -( $\alpha$ -furyl)-caproic acid exactly paralleled those that occurred on the reduction of *l*- $\beta$ -( $\alpha$ -furyl)-valeric acid. The stepwise reduction of *d*- $\beta$ -( $\alpha$ -furyl)- $\beta$ -phenylpropionic acid should, according to the theory, yield two acids having the same sign as the unreduced acid; for, the E.S.A.'s of the tetrahydrofuryl and furyl groups are intermediate between those of  $\text{C}_6\text{H}_5$  and  $\text{CH}_2\text{COOH}$ , while that of *n*-butyl is less than  $\text{C}_6\text{H}_5$  and H. This was found to be true experimentally.

# INFLUENCE OF SOME SOIL AND CULTURAL PRACTICES ON THE SUCROSE CONTENT OF SUGAR BEETS<sup>1</sup>

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The acre yield of sucrose from sugar beets grown in Iowa was found to vary widely with the farm and the season. The sucrose yield may vary from 600 to more than 5,000 pounds per acre. Large portions of this variation in yield may be attributed to soil and weather conditions, cropping practices, and destructiveness of crop diseases and insects. Nagel and Leonard (9) have shown the sugar variation incident to *Cercospora* leaf spot injury. It seemed desirable to determine what environmental factors were primarily concerned and how these factors might be controlled or their effect circumvented or nullified.

The present communication reports the results of investigations into the effect of such factors as time of planting, type of soil, time of harvest, and rainfall during the harvest period.

## METHODS

The beet samples used in these investigations were obtained from commercial fields in most cases. In 1937 and 1939 all samples were obtained from growers' fields or experimental fields designed for large scale yield tests. The 1940 samples were taken from a large varietal yield test field. In 1938 plots of 1/6 acre were set up in commercial fields. These plots, however, were located, planted, cultivated, and harvested with the purpose of obtaining the data reported.

In all cases the beet samples consisted of 15 competitive beets (2) obtained at random within as small an area as possible. Three such samples were taken at random from each 1/6- to 1/2-acre plot or test field area. The soil samples for moisture determination, 1 to 3 per beet sample, were collected from soil adjacent to beets used in the sample. The soil from the 1- to 3-inch level was used in all samples.

After digging by hand the beets were placed in beet sacks, taken to the laboratory, sampled by means of a standard rotary beet rasp, and the composite pulp samples tested for percentage of sugar according to the method published in the Association of Official Agricultural Chemists Handbook (1). Samples of this pulp also were used for moisture determination. After weighing, the pulp was dried for 48 hours at 95°C. and reweighed. Soil moisture was similarly determined.

The weather records were obtained from the official United States Department of Agriculture weather reports for the area around Kanawha, Iowa.

<sup>1</sup>Journal Paper No. J-983 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 449.

## VARIATION IN COMMERCIAL FIELDS

The 1937 tests were conducted on commercial beets obtained from 3 to 5 different growers<sup>3</sup> at each of 5 loading stations in the northern Iowa sugar beet district: Belmond, Britt, Clarion, Hutchins, and Kanawha. At each sampling date, three samples of 15 representative beets were obtained from loads from each grower and the percentage of sugar in the pulp determined. The yield in tons per acre, the contract pay basis per ton and the actual payment on a per acre basis were obtained for as many of the 21 growers as possible.<sup>4</sup> On the basis of the data in Table 1, it was obvious that considerable variation existed in the growers' fields in the yield of sucrose produced per acre. The variation in sucrose produced on an acre basis varied from 2,023 pounds to 4,417 pounds. The highest yield of sucrose per acre resulted from a field yielding the greatest tonnage and the highest percentage sucrose. The lowest tonnage yield and the lowest percentage sugar did not occur in beets from the same field. There seemed to be no relation between tonnage of beets and percentage of sucrose in the beets.

The growers' contracts call for payment on the basis of sucrose in the tonnage grown, figured on the basis of the average percentage sucrose for the beets grown in the district. It was desirable, therefore, to determine the action of various factors that tend to produce large tonnage of beets with as high a sucrose content as possible. The system of payment placed a premium on a large tonnage of beets regardless of sucrose content. It would further increase the payments to the grower, however, and lower the cost per beet of processing if the time of harvest could be fixed at the time of highest sucrose content per beet.

## VARIATION CAUSED BY DATE OF PLANTING

The time of planting sugar beets was known to influence the sucrose yields, but little was known of the range of the variation. Nuckols (6) suggested that since beets require a long growing period, they should be planted early. Knight (4) reported results from 9 planting dates. He found that the yield obtained from the plots planted on the earliest date (April 23) was the greatest. Later dates of planting resulted in lower yields.

The date of planting was known for only 13 of the 21 fields sampled in 1937 (Table 1). Of these, 5 were planted during the first half of May, 3 during the last half of May, and 5 on June 1 or later. In 1938 the plots were planted at definite times. Data were obtained from 10 fields planted April 29, 11 fields planted on May 12, and 12 fields planted on May 29. The average percentage sucrose, the yield of beets in tons per acre, and the calculated pounds of sucrose per acre are reported in Table 2.

It may be noted that in 1937 the early plantings had a slightly higher

<sup>3</sup> The authors wish to acknowledge the valuable assistance of Mr. Wallace C. Darrah of the American Crystal Sugar Company in choosing representative growers.

<sup>4</sup> The authors are grateful to the American Crystal Sugar Company for supplying and allowing the use of various of these data.

TABLE 1

AVERAGE SUGAR PERCENTAGE, YIELD OF SUGAR BEETS PER ACRE AND POUNDS OF SUCROSE PER ACRE, PRODUCED BY INDIVIDUAL GROWERS, 1937

GROWER	LOADING STATION	PLANTING DATE	PERCENTAGE SUCROSE AVE.	YIELD T/A	SUCROSE LB./A (Approx.)
A.....	Belmond	*	14.98	9.39	2,813
B.....	"	May 14	15.00	10.76	3,228
C.....	"	June 18	13.36	7.57	2,023
D.....	Britt	May 10	15.39	9.20	2,832
E.....	"	*	14.37	10.88	3,127
F.....	"	*	15.05	10.86	3,270
G.....	"	May 4	16.48	13.40	4,417
H.....	"	*	15.21	13.31	4,049
I.....	Clarion	*	14.06	9.28	2,567
J.....	"	June 1	15.06	12.46	3,753
K.....	"	*	14.26	11.84	3,377
L.....	"	May 20	14.24	13.12	3,736
M.....	"	May 30	14.80	10.06	2,978
N.....	Hutchins	*	12.84	9.31	2,391
O.....	"	June 4	14.45	10.33	2,985
P.....	"	May 1	14.26	11.41	3,254
Q.....	Kanawha	June 1	14.95	8.83	2,640
R.....	"	June 1	16.26	11.19	3,639
S.....	"	*	11.85	9.84	2,332
T.....	"	May 18	15.08	8.04	2,425
U.....	"	May 6	15.65	11.84	3,706

\*Planting date not known.

percentage of sucrose as well as a larger yield of beets, resulting in more sucrose per acre. This would tend to indicate a definite advantage to early planting. It should be pointed out, however, that the two fields having the lowest percentage sucrose, as observed from the averages in Table 1, were among the fields of unknown planting dates. Therefore, some doubt might

TABLE 2  
THE AVERAGE PERCENTAGE SUCROSE AND YIELD PER ACRE FROM SUGAR BEETS PLANTED AT  
DIFFERENT DATES

DATE OF PLANTING	NO. OF PLOTS	PERCENTAGE SUCROSE AVE.	AVE. YIELD PER ACRE	
			Tons Beets	Lbs. Sucrose
1937				
May 14 or before.....	5	15.36	11.32	3,487
May 18-30.....	3	14.71	10.41	3,046
After June 1.....	5	14.81	10.07	3,008
All plots—.....	21	14.65	10.61	3,121
1938				
April 29.....	10	12.3	14.35	3,630
May 12.....	11	12.3	13.81	3,397
May 29.....	12	12.8	10.58	2,708
All plots.....	33	12.4	12.80	3,182

be thrown on the validity of the data. On the other hand, it might merely indicate that records of planting dates indicate generally superior farming practices.

In 1938 a severe epiphytotic of *Cercospora* leaf spot, which occurred approximately a month later than usual, not only markedly lowered the general average of percentage sucrose in the beets (*see* Nagel (8)) but also obscured any difference in sucrose content between the two early plantings. The epiphytotic was severe and late enough that at the time the beets were harvested 60 per cent or over of the set of leaves then on the plants were infected to such an extent as to be recorded as non-functional (8). The average percentage sucrose in the fields under observation was about 12.4 with no field averaging above 14.5. The previous year similar fields had an average of 15.0 to 16.3 per cent sucrose.

The leaf spot epiphytotic may or may not have been responsible for the higher sucrose percentage at the late planting date, since the younger beets suffered less defoliation than earlier planted beets and would be expected to show a correspondingly smaller decrease in the sucrose percentage. It should be noted, however, that although the leaf spot epiphytotic seemed to have a marked effect on the sucrose percentage, it had no such effect on the yield of the early planted beets, which, therefore, contained on an acreage basis more actual sucrose than those planted later. It would appear that although late planted beets did not suffer as marked a reduction in sucrose percentage, the development of the

root was definitely inhibited as indicated by the tonnage yield. Thus, in spite of the deleterious effect of a late epiphytotic of *Cercospora* leaf spot, the value of early planting is nevertheless evident. This effect is clearer in the more detailed results reported in Table 3.

In 1939 two fields with early and late plantings were sampled. The difference in percentage sucrose between early and late planting was not great in either field. The difference was, however, just reversed in the two cases. Since no yield data were available, further analysis was not possible.

#### VARIATION CAUSED BY SOIL TYPE

The information available concerning the value of different soils for growing sugar beets is rather conflicting. Lill (5), Roeding (10), Saylor (13), Urban (15), and Wiley (17, 18) found that the nature of the soil, mineral or organic, was not important in determining the sucrose content of the beet so long as the soil was deep, nearly neutral in reaction, friable, not too heavy, and well drained. Wiley (18) noted, however, that an excess of soil nutrients produced vegetative overgrowth and a consequent reduction of sugar content, whereas, insufficient soil nutrients tended to limit vegetative growth and to increase the sugar content of the root. Saylor (13) pointed out that the stiff clays or heavy swamp mucks did not produce sugar beets of good quality. Dowling (3) reported a sucrose content of 18 to 20 per cent on light sandy loams and 13 to 14 per cent on peaty soils. The latter was said not to be always true, for some alluvial fen soils yielded heavy crops with a high sucrose content.

The 1937 data were obtained from samples taken at the loading stations, and only few data were procured on the nature of the soils in which the beets had been grown. From these few data, however, it became apparent that beets from muck soils were definitely inferior in percentage of sucrose. This fact had been reported in the literature by Dowling (3), Saylor (13), and Wiley (18), but little or no supporting data were given. The variation in yield and percentage sucrose was investigated more thoroughly in 1938.

Beets were planted in 1938 at three different dates on each of three soil types, Clarion sandy loam, Webster silty loam, and muck. Where possible, comparable plantings were made on each of five farm fields of each soil type. Within a field these plantings were in as close proximity as possible. The average results for the three planting dates on each of the three soil types are reported in Table 3. The severe late leaf spot epiphytotic in September as mentioned above had eliminated most of the differences attributable to date of planting. It was evident that beets in muck soils were characterized by a percentage of sucrose of only  $\frac{5}{6}$  that of beets in the mineral soils, and a yield about  $\frac{7}{6}$  that of the beets in the mineral soils. The sucrose percentage from beets grown in muck soil was below the level of rejection contained in most contracts. Crops on muck soil lowered the percentage sucrose for the entire area, but growers of



TABLE 3  
THE PERCENTAGE OF SUCROSE, PULP MOISTURE, AND SOIL MOISTURE FOR SUGAR BEET PLANTINGS MADE AT THREE DIFFERENT DATES ON THREE DIFFERENT SOILS IN 1938

	EARLY PLANTING			MEDIUM PLANTING			LATE PLANTING		
	Clarion	Webster	Muck	Clarion	Webster	Muck	Clarion	Webster	Muck
No. plots.....	4	5	1	4	5	2	4	6	2
Percentage sucrose.....	12.55	12.78	10.00	12.41	12.70	11.02	12.97	13.06	11.35
Percentage moisture in pulp.....	81.66	81.73	84.40	81.47	81.73	83.35	81.06	81.00	82.90
Percentage moisture in soil.....	22.93	24.29	36.34	21.47	23.71	37.71	21.43	23.59	37.81
Yield T/A.....	14.20	13.98	16.81	13.65	13.23	15.10	9.93	9.73	12.69

these beets received large payments because of the heavy tonnage yield obtained. Plantings on muck soils were definitely detrimental to the interests of sugar beet production in northern Iowa.

Differences similar to those observed in 1938 were also apparent in the less extensive analyses conducted in 1939 and 1940. In all three years the beets from Webster soils averaged about 0.3 percentage points more sucrose than beets from Clarion soils. This slight difference of sucrose percentage was counterbalanced by the somewhat greater yield on the Clarion soils. Since both mineral soils produced beets with sucrose percentages well within the profitable range, the data indicated the difference between the soils to be inconsequential.

#### VARIATION CAUSED BY RAIN DURING HARVEST

The effect of rain during the fall has been considered to be detrimental to high sucrose contents by most workers. The explanation for such detrimental effects vary and few data are available. Saylor (11, 12, 13), Wiley (17, 18), Lill (5), Roeding (10), and others (8, 14, 16), have agreed that rains during the latter part of September and during October were detrimental to high sucrose content of the beets. This decrease has been explained as resulting from renewed root growth (12), renewed shoot growth (10, 13), renewed root and shoot growth (11, 18) or, perhaps in part at least, from dilution of sugar in the root (8, 16). If the fall rains were heavy, the renewal of growth drained the sucrose reserves sufficiently to render the beets unsatisfactory for processing (10), especially if the rains were followed by warm weather (11, 18). In irrigated regions late irrigation has been said to be harmful to the beets (10), although more recently this has been denied and suggested as even being beneficial if moderate (7). Urban (16) in Czechoslovakia has made the most thorough investigation of the effect of rain during harvest on the sucrose content of the sugar beet. In general he found that rains of more than an inch would cause a drop of 1.12 per cent sucrose or more in the week following the rain. The drier the beet at the time of the rain, the greater was the decrease observed in the sucrose content.

The 1937 data gave an indication that the effect of a rain on the sucrose content was not completely understood. On October 16, 1937, harvesting was interrupted for 5 days by approximately 1 inch of rain. When harvesting was resumed many fields showed a sucrose content of about 0.5 percentage point lower than in October 15. This sucrose content increased to the October 15 level within 7 to 10 days. In certain fields, however, no decrease in sucrose content was observed.

Further data were collected in the following three years to determine the effect of a heavy rain on sucrose content and the proper time for resumption of harvest after a rain to avoid a loss of sucrose. In 1938 a rain of 0.92 inches occurred on October 12. Analyses of beets collected October 15 showed a slight increase over that of October 7. On October 19 the sugar analyses averaged 0.4 to 0.6 percentage points below those of October 15. On October 29 the sugar content was equal to or greater than that

of October 15. In 1939 rains totaling 1.2 inches occurred from October 5 to 9. Sugar analyses on October 16 showed an average drop of 0.8 percentage points from those of October 11. However, the variation of gains and losses were too extreme to consider this as indicative of a definite drop in sucrose.

In 1940 analyses were conducted on beets from a selected field for the purpose of collecting data on the effect of a rain. The data obtained are reported in Table 4. It will be noted that 1 inch of rain on October 6 followed by 0.31 inch on October 10 produced no effect on the sucrose content. The continuous rains from October 28 to October 31 totaling 1.68 inches caused a drop of 4.2 per cent sugar in collections on November 5. Although this was undoubtedly an extreme case, it was believed to confirm the general theory of the effect of rain on beets during harvest.

From the above results, it seemed evident that two points might be made. The effect of a rain in lowering the sucrose content of sugar beets reached a maximum approximately 7 days following the rain. This effect was not noticeable or was very slight in the early part of the harvest period, became of noticeable and harmful proportions during the middle of harvest and might be extreme if it occurred at the end of the harvest

TABLE 4

THE AVERAGE PERCENTAGE OF SUCROSE AND MOISTURE IN THE BEET PULP AND MOISTURE IN THE SOIL IN THE PLANTING SAMPLED DURING 1940

	PERCENTAGE SUCROSE	MOISTURE IN PULP	MOISTURE IN SOIL	PRECIPITATION
Oct. 2.....	12.28	80.91	24.82	.....
Oct. 6.....				1.00
Oct. 9.....	13.07	80.57	31.14	.....
Oct. 10.....				.31
Oct. 14.....	13.93	79.93	29.86	.....
Oct. 22.....	15.05	79.06	27.14	.....
Oct. 28.....				.83
Oct. 29.....	14.50	79.92	38.26	.24
Oct. 31.....				.61
Nov. 1.....	15.04	78.89	38.57	.....
Nov. 5.....	10.80	83.87	33.40	.....
Nov. 8.....	13.88	80.77	30.59	.....
Nov. 9-12*.....				2.43
Nov. 19.....	12.98	81.39	41.98	.....

\*Beets frozen in ground.

period. It would appear that if beets cannot be lifted within 3 days after an inch of rain occurring during the last half of the harvest period, they should be left in the ground at least 10 days after the rain if this is possible.

#### TIME OF HARVESTING SUGAR BEETS IN IOWA

Recommendations for the time of harvesting sugar beets are rather vague. Lill (5) and Nuckols (6) agreed that since sucrose was stored during warm fall weather, the beets should be left as long as possible before digging. Lill, however, warned against allowing the beets to be

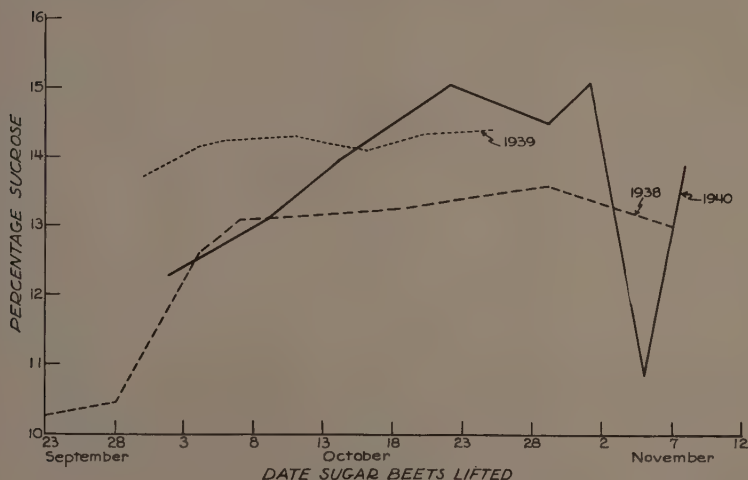


FIG. 1. The trend of sucrose content of sugar beets sampled in northern Iowa from Sept. 23 to Nov. 8 during 1938, 1939, and 1940.

frosted; Nuckols reported that frost caused no damage but made harvesting more expensive.

The average of the daily analyses of sucrose content of sugar beets sampled during 1938, 1939, and 1940 are shown in Figure 1. From the trends of the curves from these analyses, it was evident that beets lifted before October 1 would be comparatively poor in sucrose. As a result, the grower would receive less for his beets and the cost of processing the beets per hundred pounds of sugar produced would be increased. It appeared further that there was little to be gained in sucrose percentage by leaving the beets in the ground after October 7 to 10. These data suggest that sugar beet harvesting in Iowa should begin about October 1 and be completed by October 10. All beets should be lifted by the end of October to avoid the slow loss of sucrose that may occur as a result of cold weather, frost, etc.

## SUMMARY

An investigation of the factors affecting the sucrose percentage of sugar beets grown in northern Iowa was conducted from 1937 to 1940.

The average per acre production of sucrose in different commercial fields varied from 2,023 pounds to 4,417 pounds. Sucrose percentage ranged from an average of 11.85 to 16.48, and the yield of beets from 7.57 to 13.40 tons per acre. The highest sucrose yield resulted from the greatest tonnage and the highest percentage sucrose. No relation, however, was found between the tonnage and percentage sucrose of beets.

In 1937 the average production of sucrose (pounds per acre) on 5 fields planted before May 14 was 3,487 pounds, whereas that on 8 fields planted after May 18 was 3,023 pounds. Ten fields planted on April 29, 1938, yielded an average of 3,630 pounds of sucrose per acre, but 12 fields planted on May 29 produced an average of 2,709 pounds.

Although the tonnage yield of beets was greater on muck soil than on mineral soils, beets grown on mineral soil yielded a higher percentage of sucrose than those grown on muck soil. For example, the percentage sucrose in beets grown on Clarion sandy loam was 12.55; on Webster silty loam, 12.78; and on muck soil, 10.

The maximum percentage of sucrose was not obtained in sugar beets harvested before October 1 in 1938, 1939, and 1940. Little appeared to be gained in sucrose percentage, however, by leaving the beets in the ground after October 7 to 10.

When an inch or more of rain fell during the last half of the harvest season, or after October 15, the sucrose percentage did not decrease over 0.2 percentage points in the first 3 days following the rain, but after 7 to 10 days the decrease amounted to from 0.5 to 4.2 percentage points. After this time the sucrose percentage increased. Indications were that if beets cannot be lifted within 3 days following an inch of rain occurring during the last half of the harvest period, they should, if possible, be left in the ground at least 10 days after the rain.

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# THE RELATION OF SECONDARY PLANT SUCCESSION TO SOIL AND WATER CONSERVATION<sup>1</sup>

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In many areas in the United States, soil erosion has progressed to a point at which little or none of the fertile top soil remains. Such areas are of little value for agriculture unless given treatments expensive in labor, fertilizers, seed, and engineering structures. Many of these areas have been and are being abandoned. When man's disturbing influence on these eroded areas is removed or materially lessened, reclamation through the invasion and development of natural vegetation becomes evident. If gullying is not too far advanced, weed communities invade and take possession. The presence of the weeds ameliorates the aerial factors, improves the structure of the soil and increases its fertility by the addition of organic matter so that the modified conditions permit the development of plant covers of increasing density and volume until the final vegetation type which the climate will support (the climax) is reached. This complete process is known as secondary plant succession.

Vegetative cover is one of the few factors affecting the rate of soil erosion which can, to any appreciable extent, be controlled by man. Studies have been made of the successional stages of herbaceous and woody plant covers of the soil and of the effect of these natural plant covers and of crop covers on the rate of runoff and erosion (1, 2, 6, 8, 12, 13, 17, 18, 19). Very little, however, is known of the effect on the rate of soil erosion, of plant communities which invade bare eroded areas and, by successive stages of secondary plant succession, modify the site until the climax vegetation stage again develops. In the attempt to establish adequate plant covers on bare eroded soils, much can be learned from a study of this natural method of reclothing bare areas with vegetation.

The object of this paper is to present the facts of secondary plant succession in central Iowa which are pertinent to a study of the establishment of protective vegetative covers and to evaluate the effect of the vegetation of each stage of the succession on soil and water conservation.

## EXPERIMENTAL METHODS AND RESULTS

Intensive studies of the development of the plant communities which make up the various stages and their relationship to soil and water conservation were made in and near a large gully 5 miles northeast of Ames. Extensive studies of secondary plant succession were made in disturbed areas in the surrounding region. Response of various erosion control

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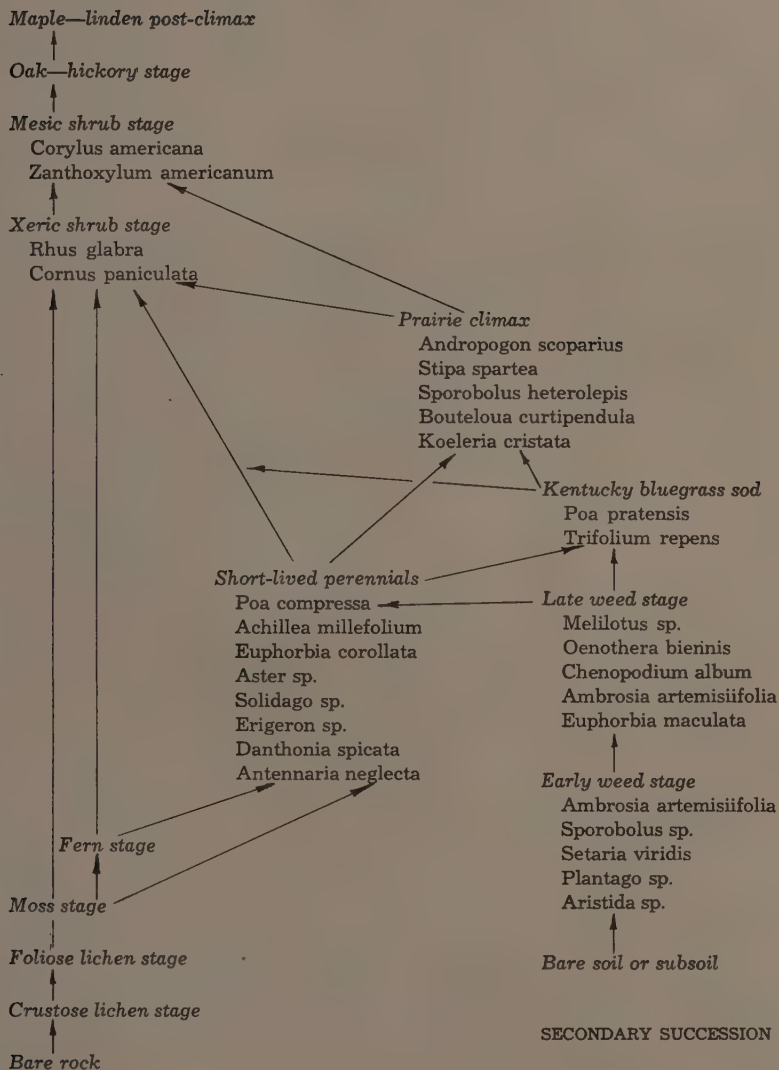
plants on soils of 4 of the distinctive successional stages found in the field were investigated in the greenhouse. The gully selected for intensive study was a V-shaped cut through the poorly developed Conover fine sandy loam into the highly calcareous subsoil. This soil is a shallow forest soil derived from Wisconsin drift. The gully had developed by erosion from a borrow-pit. A general view of a portion of the gully and one of the erosion traps is shown in Figure 1.



FIG. 1. A general view of a portion of the gully, showing the instrument shelter on the nearly bare west slope and one of the erosion traps in the right background.

As a result of the extensive studies a chart was made (Fig. 2) of the stages of the secondary plant succession in central Iowa. The relationship existing between the stages of secondary and primary plant succession is shown in the chart. The later stages of succession are the same whether the early stages are primary or secondary.

Five stages of the secondary succession were selected for study. A denuded check area was used to determine the rate of runoff and erosion from soil not affected by the presence of vegetation. The vegetation of the early weed stage was made up of species of *Ambrosia*, *Sporobolus*, *Setaria*, and *Aristida*, and had a basal area of 0.5 per cent. The late weed stage as represented in the gully had *Melilotus officinalis* as a dominant with a denser stand of the weeds which were present in the early weed stage. The average basal area was 1.2 per cent. The short-lived perennial stage (Fig. 3) had an average basal area of 6 per cent and the Kentucky bluegrass had a basal area which varied from 12 to 18 per cent. Of the two stages represented by forest communities (Fig. 2), the final post-climax



## PRIMARY SUCCESSION

FIG. 2. Chart showing the relationship of the stages of primary and secondary plant succession. The plant species of the stages are those of central Iowa. The relationship of the stages as shown is applicable to the entire prairie climax region of central United States.

stage, the maple-linden, was selected for study. It had a very low basal area but an average top cover (canopy) density of 90 per cent.

The intensive phase of this study was made during the drought year of 1936 when only one small rain fell in May and there was no rainfall between June 27 and August 3. During most of the summer, the temperature was high; the average diurnal temperature for July and August was 90°F. The average diurnal relative humidity for this entire period was only 45 per cent. The hygrothermograph from which the readings were taken was located on the west slope of the gully and was protected from the direct rays of the sun. Comparisons of diurnal temperature at the soil level showed that bluegrass cover reduced the temperature 10 to 12 per cent below that of bare soil and that the maple-linden woods caused another 10 to 12 per cent reduction.

The dryness of the air about one foot above the ground, as tested by atmometer readings of evaporation rate, was 36 per cent greater in the open on the west side of the gully than on the north slope under the maple-linden woods. Readings of radiant energy, which accounted for the greater part of the above difference in evaporation rate were 100 per cent on the bare slope, over 90 per cent under the vegetative cover of the first and second weed stages, and only about 3 per cent under the maple-linden cover. The dry condition of the air immediately above the almost bare soil of the two weed stages contributed to the dry condition of the top six inches of soil in these two stages. The low rate of percolation of water in the soil of these two stages, as shown by the high rate of water loss following rains, seemed to be the other important contributing factor, since the volume of vegetation was so low that there was little loss of water from the soil by transpiration.

Available moisture was lacking most of the summer in the surface 6 inches of the bare soil plots of the first two stages of the succession, but there was at least 5 to 15 per cent available in the other stages. In the second 6-inch layer of the soil in the first two stages there was only 3 to 5 per cent of available moisture and in the second foot only 6 to 7 per cent. Rate of percolation was much higher in the soil of the maple-linden forest as shown by the low water loss from the erosion trap, and percentage of available moisture to a depth of two feet was much greater, as shown by soil borings, in spite of the use of large quantities of water by the trees in this stage. However, at no time during the dry summer and fall was there more than 3 to 4 per cent of available water at the 3-foot depth in the maple-linden. The paucity of water at this depth would seem to indicate that percolation rate would have continued to be high with an increase in precipitation.

The soil of the bare soil plots was low in organic matter (.24 per cent), of poor structure, and was easily puddled by beating rains. The organic matter of the soil of the first two successional stages, although over twice as great as in the bare plots, was also low, and soil structure was correspondingly poor.

Erosion traps of a modified Bates and Zeasman type (6) were set up in

a series of 1/500 acre (6.6 x 13.2 feet) plots in 5 stages of the succession and in one denuded plot (Fig. 3). The run-off water and eroded material was caught in 21-gallon galvanized iron cans. The water was measured after each rain and a representative silt sample was taken to the laboratory and oven dried to determine the quantity of silt. For comparison the data were calculated on the basis of 40 per cent slope which was approximately the average degree of slope.



FIG. 3. The short-lived perennial stage which had a basal area of 6 per cent, June 1936. The type of runoff and erosion traps used in the study is shown.

Total water and soil loss in gallons and pounds per acre for the 15 rains from June to September are graphically represented in Figure 4. The water loss from the short-lived perennial stage in this series was higher in proportion to the two weed stages than occurred in other tests made. This increase is attributed to the fact that there were more rock fragments in this site which had formed a quite well-developed erosion pavement in spite of the fact that the plant cover had reached the third stage in the secondary succession. Although a small decrease in rate of water loss might be expected in successional order in the first three stages following the invasion of a bare area, any such decrease would be slight for the changes which the small volume of plant cover has made on the structural characteristics of the soil, contributing to increased percolation rate, are very meager.



The comparatively high rate of water loss from the bluegrass sod as shown in Figure 4 was confirmed in other experiments by approximately the same results where the site had been moderately grazed as it was here. In general, however, the slight increase in the quantity of water

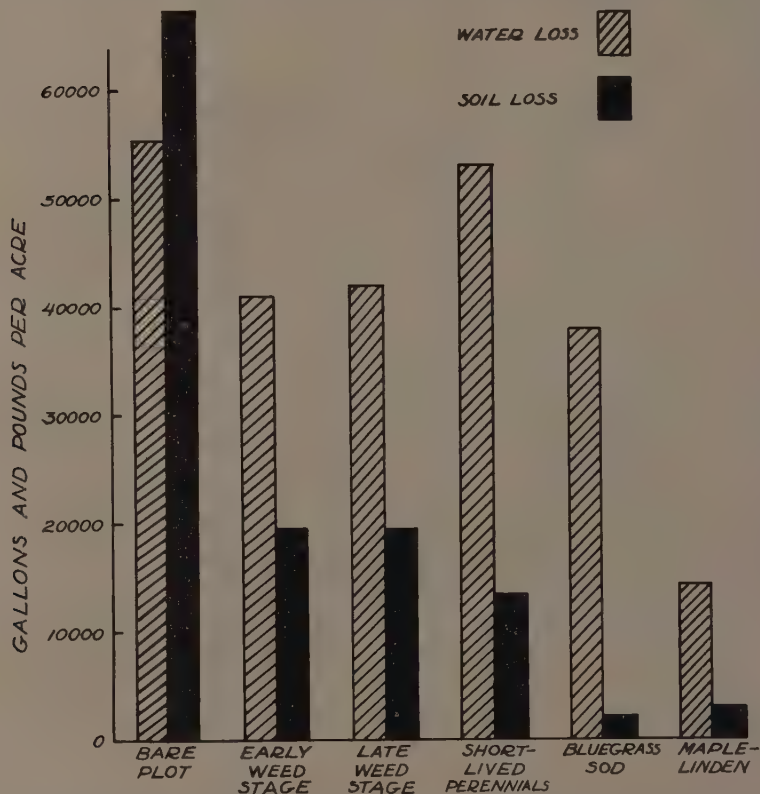


FIG. 4. Total water loss in gallons per acre and soil loss in pounds per acre, calculated on the basis of 40 per cent slope, for the stages of secondary plant succession. June to September, 1936.

found in the soil in the bluegrass stage over the first two stages and the slightly greater loss of water by transpiration from the bluegrass than from the plants of the other two stages would not require a quantity of water much greater than that accounted for by the decrease in rate of runoff in the bluegrass as compared to the first two stages. It was noted also during rains that the bluegrass cover, under the condition of partial cropping and moderate packing as under moderate grazing, allows a relatively free movement of water between and along the blades of grass

if the slope is as great as 40 per cent. These data would seem to indicate that bluegrass pastures have probably been over-rated as water conserving plant covers.

The maple-linden community, although almost completely unprotected at the ground level, had only one-fourth as much water loss as the bare area and slightly over one-third as much as the bluegrass pasture with 12 to 18 per cent cover at the surface of the soil. However, a top cover (canopy) density of 90 per cent reduced the force of the rain, and the high yearly yield of readily decomposed organic matter over a long period of time had improved the structure of the soil to a degree that induced a high rate of water percolation.

The results summarized in Figure 4 show that although there seems to be less relationship between the stage of development in the secondary succession and the rate of water loss than might be expected, there is a definite relationship between the stage of development and rate of soil loss. The only anomalous fact in the series is the almost identical soil loss from the early and late weed stages. This may be attributed in part to the similarity in quantity of water lost from the two sites which would indicate almost equal soil-carrying capacity provided there was little difference in soil protection. The degree of protection at the surface of the ground afforded by the larger number of smaller plants was greater in the late weed stage, but this was probably offset to some extent by the slightly better protection immediately below the ground of the root systems of the larger, better-developed plants of the early weed stage. The much greater soil-holding capacity of the fibrous root system of the bluegrass sod at the ground level as contrasted to the absence of soil-holding plants at the ground level under the maple-linden forest would seem to account for the greater loss of soil from the maple-linden site than from the bluegrass site in spite of the fact that there was much more loss of water from the bluegrass sod. In fact the clearness of the large quantity of water from the bluegrass indicated that it had come in contact with very little unprotected soil.

The influence of the quantity and intensity of rainfall on soil and water loss are shown in Figure 5. The quantity was relatively much reduced for rains under 0.4 inches, but the relationship between soil and water loss was approximately the same for the different intensities of rainfall. Combining the data from the three early stages it was found that the soil loss from one 2-inch rain was nearly twice that caused by 4 rains totaling 2 inches and 4 times that caused by 8 rains totaling 2 inches. Runoff was greater for the 4 rains than for the single 2-inch rain but only half that for the 8 rains, which totaled 2 inches.

In the forest with its 90 per cent canopy, interception was a very important factor for the light rains. The average interception for 10 rains below 0.4 inches was 20 per cent. It was 14.2 per cent for an average of 6 rains between 0.4 and 1.0 inch. Four rains between 1 and 2 inches had an average interception of 4.1 per cent. For rains over 2 inches average interception was less than 1 per cent.

Under average conditions in central Iowa it requires at least 50 years for the development of secondary plant succession to the initiation of the oak-hickory forest stage. The rate of succession and nature of the plant cover are dependent on factors intimately associated with water and soil

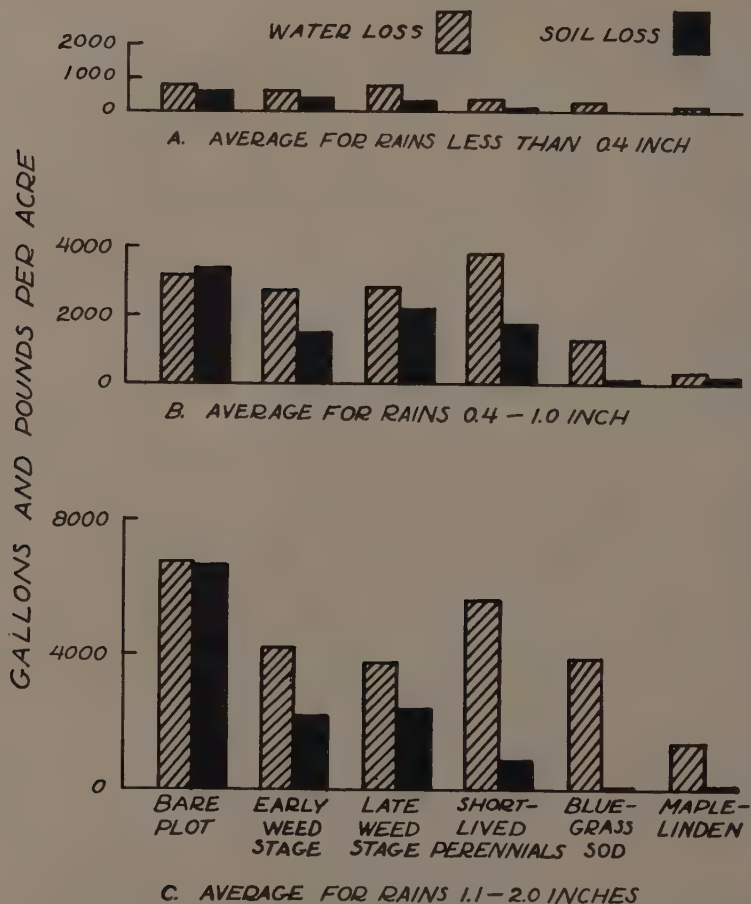


FIG. 5. Influence of size of rain on soil and water loss in 6 successional stages. June to September, 1936.

loss. The edaphic factors of texture, structure, and depth of soil, the percentage of available water and nutrients, the percolation rate and capacity (4, 10, 11, 13, 14); the physiographic factors of slope and aspect; and the climatic factors of temperature, relative humidity, rate of evaporation,

and the total quantity of precipitation (5, 13) all affect and are affected by rate of runoff and erosion and by the existing plant cover. There is an increase in density and quantity of plant cover and a slow increase in rate of soil building as progress is made in secondary plant succession from the early stages toward the climax or postclimax.

The importance of preserving the A horizon of soil profiles was demonstrated by Sinclair and Sampson (16) who planted native and crop plants on the soils of the A, B, and C horizons. Rate of growth and quantity of plant material produced was greatest and the number of days required for production of flowers and fruit was least for plants grown on the A horizon as compared to plants grown on the B and C horizons. Establishment of climax and subclimax plants where the A horizon had been removed was retarded or prevented. In nature early stages of the succession must prepare the way for the establishment of the perennial plants of the later stages. In the present problem there were indications of similar difficulties in succession on the badly eroded soils, so the following experiment was undertaken.

Soil collected to a depth of 6 inches as large composite samples from 4 plant communities, representing stages of the secondary plant succession in central Iowa, were taken into the greenhouse, sifted through a  $\frac{3}{8}$ -inch screen, thoroughly mixed, and placed in deep flats for planting. Some of the properties of the soils are given in Table 1. The soils of the first 3 stages were slightly alkaline in reaction and very low in organic matter.

TABLE 1

CHARACTERISTICS OF SOIL FROM PLANT COMMUNITIES USED IN GREENHOUSE SEEDLING AND TRANSPLANT EXPERIMENTS: WATER-HOLDING CAPACITY, WILTING PER CENT AND ORGANIC MATTER IN PERCENTAGE DRY WEIGHT OF SOIL

STAGE	SOIL CHARACTERISTICS	WATER-HOLDING CAPACITY	WILTING PER CENT	ORGANIC MATTER	pH
(1) Early weed...	Yellow calcareous clay, heavy	22.	5.5	0.24	7.3
(2) Late weed...	Similar to (1), coarser texture	28.	5.3	0.68	7.3
(3) Short-lived perennial...	Soil more leached and of lighter structure than (2)	29.	5.4	0.67	7.4
(4) Sumac and hazel shrub...	Conover fine sandy loam	35.	4.4	2.23	6.8

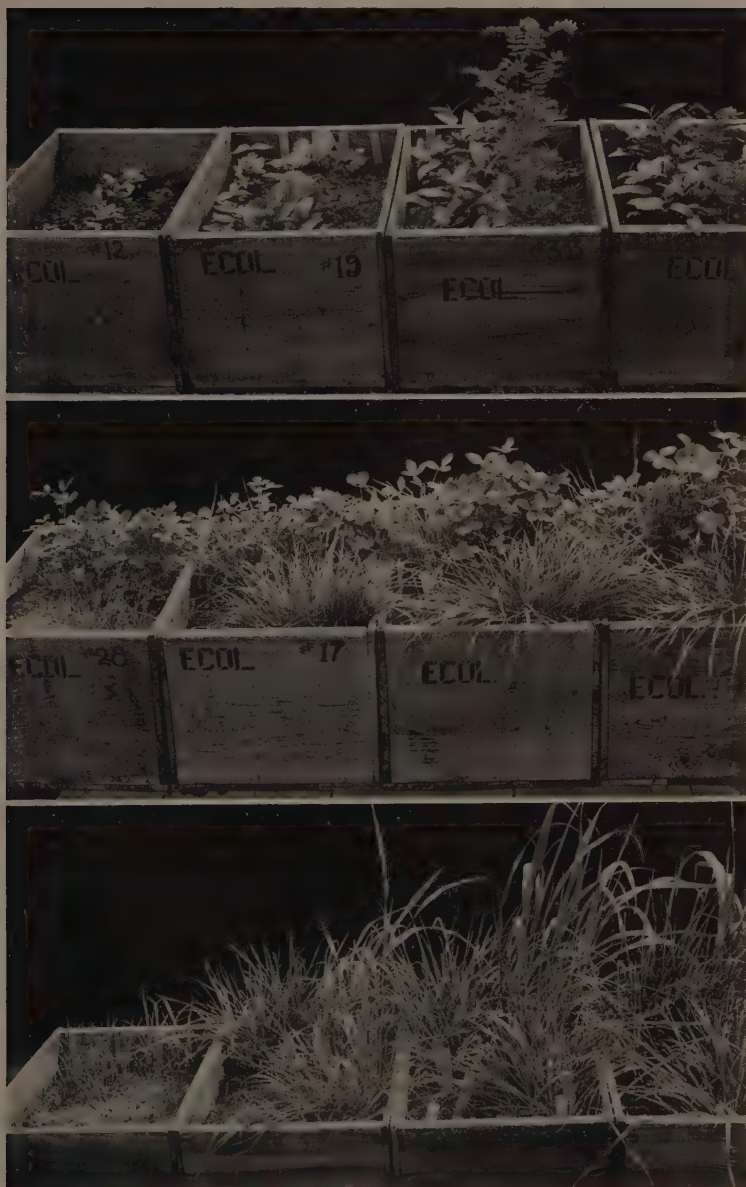
The soils were placed in 10-inch flats and planted in December to woody and herbaceous species selected chiefly for their ability to grow on poor, thin soils. Light was a limiting factor because of the short winter days. The day temperature varied from 70° to 80° F., and the night temperature was reduced to about 55°. The flats were kept watered at ap-

TABLE 2  
AVERAGE HEIGHT GROWTH IN CENTIMETERS OF WOODY AND HERBACEOUS SPECIES GROWN  
IN GREENHOUSE

SOIL OF THE FOUR STAGES	EARLY WEED	LATE WEED	PERENNIAL	SHRUB
Average of 13 Weeks' Growth				
<i>Woody Species</i>				
Caragana arborescens.....	2	5.5	16	10
Catalpa speciosa.....	6	7.5	8.5	11
Ceanothus americanus....	3.5	8.5	9	13
Cercis canadensis.....	4	6	9	.....
Eleagnus commutata.....	3.5	5	7	6
Physocarpus opulifolius....	3	4	7	7.5
Robinia pseudoacacia.....	7	10	13	20
Rhus canadensis.....	.....	3	3.2	3.5
Rhus glabra.....	3.5	4	6.5	.....
Average of 8 Weeks' Growth				
<i>Herbaceous Species</i>				
Agropyron repens.....	13	22	23	30
Agropyron tenerum.....	13	25	24	28
Agropyron Smithii.....	13	26	35	28
Andropogon furcatus.....	5	6	14	4
Andropogon scoparius....	6	9	8	6
Cynodon dactylon.....	.8	2.0	6	10
Elymus virginicus.....	9	12	18	10
Festuca elatior.....	16	23	30	36
Lolium perenne.....	12	22	25	30
Melilotus alba.....	15	15	14	14
Phleum pratense.....	7	10	24	24
Poa pratensis.....	4	9	12	13
Sorghastrum nutans.....	4	9	4	.....
Sorghum halapense.....	20	39	33	55
Sorghum vulgare.....	2	2	6	.....
Sporobolus cryptandrus....	.4	1.0	1.5	.8
Trifolium pratense.....	14	15	21	24
Trifolium repens.....	6	9	11	15

proximately the soft ball stage of the soil. Table 2 lists the average growth of the 4 replicates of each species planted in the 4 soils after 13 weeks for the woody plants and 8 weeks for the herbaceous plants. Robinia (black locust) grew especially well, exceeding all other species in the poor as well as in the better soils. Aeration, which seems to be an important factor in the growth of black locust, was favorable for all of the soils because of the small quantity of soil (approximately one cubic foot) and favorable drainage from the flats. Ceanothus and Caragana also

FIG. 6. Response of plants to soils of 4 successional stages, left to right: early weed, late weed, short-lived perennial, and shrub stages. In the upper row are catalpa, New Jersey tea, and partridge pea, 5 months after planting; in the middle row, sweet clover, red clover, Kentucky bluegrass, and perennial rye grass, 4 months after planting; in the lower row, wheat grass, Indian grass, wild rye, and fescue grass, 4 months after planting.





made good growth and developed a fair quantity of cover. Caragana made better growth in the soil of the short-lived perennial stage than in the soil of the shrub stage.

Of the herbaceous species, the legumes showed proportionately much



FIG. 7. Transplants, two rows each, of osage orange, black locust and honey locust in the 4 soils (early successional stages on the left) at the end of 12 weeks in the greenhouse. Honey locust made the greatest growth and osage orange the least.

better growth in the soil of the 2 weed stages, as compared to the 2 later stages, than did the grasses (Fig. 6). Sweet clover developed more height in soil of the weed stage than in the other soils. In Figure 6 (upper row) the growth of woody species after 5 months and herbaceous legumes and grasses (middle and lower rows) after 4 months of growth are shown. Differences in response of the plants, especially the woody species, did not become apparent until 2 months after planting. It was also observed that germination was more rapid in the soils of the higher stages.

Transplants of nursery stock of the same woody species in the 4 soils gave a response similar to that of the seedlings. These results are shown in Figure 7. Honey locust was the slowest to resume growth following transplanting, but it made the greatest growth of the 3 species of seedlings. The seedlings of each species were of equal size when transplanted in the tiles containing composite samples of the 4 soils. Two seedlings of each stage showing average growth of the 4 replicates of each species are shown in the Figure. Least growth and least variation in growth among the 4 soils were shown by the osage orange, and greatest growth and greatest variation in growth were shown by the honey locust. Lack of variation

in rate of growth of black locust in the 4 soils indicates that black locust makes satisfactory response even in poor, thin soils provided moisture supply and aeration are adequate.

#### DISCUSSION AND SUMMARY

Three interrelated elements have a bearing on the process of secondary plant succession: the soil, the vegetation, and the climate. The soil and the vegetation develop together, each affecting the other and tending to give the fullest possible expression of the climate. The developmental effect of the climate on the soil is chiefly through the reaction on the soil of the type of vegetation which the climate and soil will support. As successive stages of vegetation develop with accompanying soil changes, various climatic and edaphic factors are ameliorated chiefly by vegetational effects.

The vegetation of a given stage of development reacts on the climatic factors of the immediate habitat by a decrease in temperature induced by a reduction in radiant energy, an increase in relative humidity, a decrease in wind velocity, and a resulting decrease in rate of evaporation. The daily and periodic variation in the climatic factors are reduced in proportion to the density of the vegetation.

The reaction of the vegetation on the soil is direct as well as indirect through the amelioration of the climatic factors. The soil is protected from the force of the rain in proportion to the density of the top cover of the vegetation and is held in place against the erosive action of a given quantity and velocity of water in proportion to the protection afforded by the vegetation at the surface of the soil. Although temporary retardation of water movement at the soil surface is an important effect of vegetative cover, reduction in rate of runoff of water which actually reaches the soil surface, is proportional to the rate of percolation which is influenced chiefly by the structure of the soil. Under natural conditions, improvement in soil structure is induced chiefly by the organic matter added to the soil by the decomposition of the dead plant parts supplied by the vegetative cover of the soil.

The increase in quantity of soil moisture attributable to an increased rate of percolation and greater water-holding capacity of the soil opens the way to the invasion of a group of plants higher in the succession to which the immediate environment of the site had previously been a barrier. The plants of the higher stage of the succession protect the soil and improve the structure to an extent that the water and soil losses are much reduced. These improved habitat conditions in turn induce the development of a more luxuriant vegetative cover, and the soil-protecting and building process is accelerated.

In the early weed stage on the Conover subsoil, the total organic matter percentage was less than .3, and the daily variation in environmental factors was extremely high. Under such conditions only plants of pioneer type invaded, and rate of growth was quite low. Since top cover density was about 2 per cent and basal area about 0.5 per cent, the

soil-deteriorating processes seemed to be almost as great as the soil-building processes. Toward the close of this stage the plant cover increased but because the vegetation develops so slowly this stage is of long duration. In the late weed stages erosion was only slightly less, but the presence of sweet clover and a slight increase in volume of plant cover speeded up the soil-building processes to some extent.

When the perennial plants became established there was a marked increase in density of plant cover and a decrease in rate of soil loss resulting in improved plant growth conditions. The establishment of the short-lived perennial stage following the late weed stage, by modifying the soil and other factors, made possible the invasion of the prairie grasses, Kentucky bluegrass, or shrubs. The soil-building processes are very slow in the initial stages but are accelerated as the plants of the higher stages gain control. As the volume of the plant cover increases, the changes produced in a given period of time are of greater magnitude.

The results of the intensive field experiments show that the effect of the plant cover of the successive stages in reducing water loss is overshadowed by its effect in reducing soil loss. There seems to be a definite relationship between the soil-building properties of the vegetation of the successional stages (Fig. 4, Table 1) and the loss of soil in tons per acre. From these results it would seem that any telescoping of stages of the succession, by the introduction of adaptable plants into any stage of the succession, would be effective in soil building and thereby in erosion control in proportion to the increase in volume of plant cover thus induced.

It was shown from the results of the field experiments that even in an unusually dry year sweet clover can be successfully introduced on bare soil or into the early weed stage provided the soil is calcareous.

The results of the greenhouse experiments (Fig. 6) verified the fact that sweet clover may be successfully established in the Conover subsoil of the early weed stage and that red clover, perennial rye grass, Indian grass, and wild rye may be successfully established in the Conover subsoil of the late weed stage. The ecological equivalents of these legumes and grasses include a large number of species which may be established in Conover and comparable subsoils which have reached the late weed stage of development.

In field experiments, transplants of green ash, black locust, and Siberian pea were found to persist even on the steepest, driest sites of the early weed stage. Greenhouse experiments (Fig. 7) indicated that honey locust may be added to the list.

The results of the studies in establishment of species in soils of 4 of the successional stages indicate that the secondary successional development on eroded soils may be accelerated by the introduction of the plants showing adequate establishment in earlier stages of the succession than the stage in which they usually occur. As a result of this research there seems to be ample evidence that secondary plant succession may be controlled by man to a degree that will materially augment its effect on soil and water conservation.

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# CAROTIN—THE PRINCIPAL PIGMENT RESPONSIBLE FOR VARIATIONS IN COLORATION OF THE ADULT GRASSHOPPER, *MELANOPLUS BIVITTATUS* SAY

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Adult grasshoppers of *Melanoplus bivittatus* exhibit two distinct color types, with forms intermediate between the two. Specimens of both color types as well as intermediate forms exist within the same locality, apparently having been produced under similar environmental conditions. Mating between grasshoppers of all color phases has been observed under field conditions and in experimental rearing cages.

In the following discussion the term "light phase" is used to designate the color type of those adult grasshoppers with distinct yellow coloration on the head, dorsal stripes, sides of thorax, ventral surface of thorax and abdomen, and hind femora. The term "dark phase" refers to adult grasshoppers with no observable yellow, but with gray to bluish or purplish gray on the regions of the body enumerated above. The distribution of black pigment in either type is approximately the same, and is located as follows: a single stripe on the side and three bars on the top edge of the hind femur, a broad median stripe on the dorsum, and a stripe of irregular outline on the upper edge of each side of the thorax. Between these two distinct types there are individuals classified as "intermediate" because they possess some yellow coloration which is either inadequately distributed over the body or is lacking in intensity. When 762 adult *M. bivittatus* collected from the field were classified according to coloration, they were divided as follows: 30.3 per cent dark phase; 42.0 per cent light phase; and 27.7 per cent intermediate phase.

In this investigation the principal pigment responsible for the differentiation of the two distinct color types was identified,<sup>2</sup> and determinations were made of its intensity in the insect body.

## HISTORICAL

Colored substances of a carotinoid nature have been found in many insects, but specific references to their presence in grasshoppers and locusts are meager. Disregarding earlier indefinite references, the writers have found but one paper reporting the proved identity of carotin in

<sup>1</sup> The investigation reported here is part of the senior author's doctorate thesis research completed at the Iowa State College on a fellowship awarded by the General Education Board. He is now with the Virginia Polytechnic Institute, Blacksburg, Virginia.

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grasshoppers. Lederer (3) extracted "pure  $\beta$ -carotin" from the bright red wings of *Oedipoda miniata*, a short-horned grasshopper. His identification was by chromatographic and spectographic methods. Only traces of carotinoids were found in the blue wings of *O. coerulescens*. Tests on other insects showed that among the various pigments he obtained from the elytra of the coleopteron, *Coccinella septempunctata*, was a mixture of  $\alpha$ - and  $\beta$ -carotins. Further investigation indicated the presence of lycopin (an isomer of carotin), in the dried bodies of the hemipteron, *Pyrrhocoris apterus*.

Experimental observations made prior to 1922, concerning the presence of carotinoids in insects, are reviewed by Palmer (7, pp. 155-161). Since then Palmer and Knight (8) have reported carotin in the hypodermis of the stink bug, *Perillus bioculatus*; and in the hemolymph of the potato beetle, *Leptinotarsa decemlineata*. Fresh hemolymph of the latter had a carotin concentration of 0.0136 per cent, which is as high as in fresh green leaves. Abeloos and Toumanoff (1) considered the violet rose pigment of the anterior femora of the walking-stick, *Dixippus morosus*, to belong in the "carotinalbumins." They were able to demonstrate the presence of yellow lipochrome pigment in the integument and the blood of the same insect. Meyer (5) examined lepidopterous larvae from nine different families, and found carotin in the hemolymph. Wall (9) has reported the yellow pigment of *Aphis gossypii* to be entirely carotin. Two samples gave 0.0034 and 0.0163 per cent concentrations, based on live weight.

#### PROCEDURE

For qualitative analyses, samples of from 15 to 25 adult grasshoppers were killed in hydrogen cyanide gas, and the alimentary canals removed. The digestive tubes were not included in order to eliminate the possible inclusion of pigment in the ingested food. The remainders of the bodies were cut into small pieces and thoroughly ground in a mortar with sand and acetone. Pigments soluble in acetone were thus extracted and later purified by a procedure similar to that for separation of plant pigments (4, 6).

Water-soluble pigments were extracted by adding hot water to the ground bodies, prepared as above.

Liquid solvents were separated from the extracted solids by suction through a coarse filter.

Identification of the principal acetone-soluble pigment was accomplished by spectroscopic and chemical analyses. Spectrophotographs of the purified pigment were obtained, and locations of the absorption bands were determined by reference to a copper arc spectrum included on each photographic plate. The color reactions of the pigment when dissolved in either carbon disulfide or 95 per cent ethyl alcohol were also observed. Chromatographic analyses were made by drawing the dissolved pigment through finely-ground materials, such as calcium carbonate, mercuric chloride, calcium chloride, and powdered sucrose, tightly packed in adsorption tubes.

For quantitative determinations of the yellow pigment, the same procedure was employed as described above, except that special precautions were taken to remove all pigment. The concentrated pigment in petroleum ether solution was compared with standard 0.2 per cent aqueous solution of potassium dichromate in a Bausch and Lomb colorimeter. The amount of pigment was determined as described by Palmer (7, pp. 257-60).

## RESULTS AND DISCUSSION

The acetone-soluble extracts of *Melanoplus bivittatus* are represented largely by a single pigment. The removal of only an occasional trace of other pigment from the petroleum ether solution of pigment by treatment with 92 per cent methyl alcohol, and the failure to remove any pigment from the same solution by treatment with methyl alcoholic potassium hydroxide, indicate the yellow pigment to be composed principally of carotin, with occasionally a trace of other pigment of a xanthophyll nature.

Locations of the absorption bands obtained by spectroscopic analysis of the petroleum ether solution of yellow pigment are similar to those produced by pure carotin (Fig. 1). The locations of the former were as follows: band I, 484-473 mu; band II, 453-444 mu; and band III, 428-411 mu. Palmer (7, p. 222) has reported pure carotin in alcohol or ether solution to give the following absorption spectrum: band I, 490-475 mu; band II, 455-445 mu; and band III, 430-418 mu. Variations in width between the absorption bands reported for carotin and those yielded by the yellow pigment from grasshoppers can perhaps be explained by the difference in sensitivity of the photographic plate to the different regions of the spectrum. A difference in the refractive indices of the solvents could account for the slight shifting of the absorption bands of the grasshopper pigment toward the violet region of the spectrum.

When dissolved in either carbon disulfide or 95 per cent ethyl alcohol, the yellow pigment gave positive tests for carotin (7, p. 218), a reddish-orange color being produced in the former solvent, and a golden-yellow color in the latter.

Positive results were obtained for carotin (7, p. 219) when the petroleum ether and carbon disulfide solutions of the yellow pigment were drawn through either calcium carbonate or powdered sucrose in an adsorption tube: There was no adsorption of pigment in either case. However, when the yellow pigment solution was drawn through mercuric chloride or through calcium chloride in an adsorption tube, the results obtained were not entirely positive for carotin. It is reported (7, p. 219) that carotin is adsorbed from petroleum ether solution by finely divided mercuric chloride and calcium chloride. Only a trace of pigment, however, was adsorbed from the petroleum ether solution of grasshopper pigment. It may be that these adsorbents were not divided finely enough to hold the pigment; only ordinary mortar and pestle were available for grinding purposes.

Although the yellow pigment is often visible in the body cavity of both light and dark phase grasshoppers, it is deposited directly beneath the cuticula in only the light phase forms. In the body cavity it is particularly concentrated in the reproductive organs and surrounding fatty tissues. The pigment was found to be present in average concentrations of 0.0436 milligrams per gram of body weight in the females, and of 0.0397 milligrams per gram of body weight in the males (both determinations with the alimentary canals removed). In the reproductive organs and selected surrounding tissues, the pigment was present in a concentration

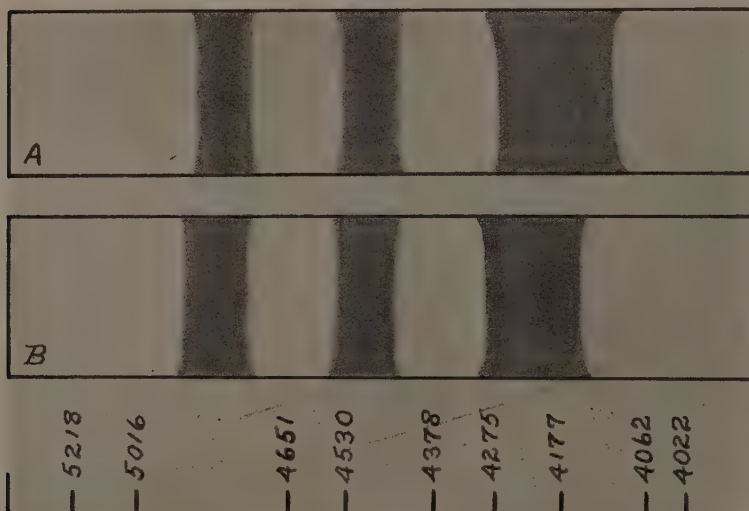


FIG. 1. A—Absorption spectrum of the yellow pigment, in petroleum ether solution, from *Melanoplus bivittatus* Say (from an original spectrograph). B—Absorption spectrum of pure carotin in alcohol or ethyl ether solution [constructed from figures given by Palmer (7)].

of 0.266 milligrams per gram of tissue. Expressed in per cent (0.0266), this figure for tissues, where the pigment is concentrated, is greater than that reported in the hemolymph of the Colorado potato beetle (0.0136 per cent) by Palmer and Knight (8).

Identification of water-soluble pigments was not accomplished. Failure of pigments extracted by hot water to become red (or purple) in acid solution, and lack of green or blue shades in neutral or alkaline solution indicate an absence of pigments of the anthocyanin group (2). Considering their possible origin, it may be that the water-soluble pigments of *M. bivittatus* are perhaps, in part, chlorophyll decomposition products, and partly certain members of the group known as the flavins. However, at present, nothing definite can be offered regarding their exact chemical nature.

No attempt was made to identify the brown and black pigments occurring in the cuticula of these grasshoppers. However, it is likely that they belong to the group of melanins commonly occurring in insects as well as other animals.

#### SUMMARY

1. Color variations of the grasshopper, *Melanoplus bivittatus* Say, occurring under similar environmental conditions are described. Percentages of each color type as found in the field are: dark, 30.3 per cent; light, 42.0 per cent; and intermediates, 27.7 per cent.

2. The color type of these adult grasshoppers is largely determined by the presence, or absence, of yellow pigment immediately beneath the cuticula.

3. Procedures used in the extraction of various pigments, and in the identification of the principal yellow pigment, are described.

4. Spectroscopic and chromatographic tests identified the main yellow pigment as carotin, with occasionally a trace of other pigment of a xanthophyll nature. It is often present in the body cavity of both color types of these grasshoppers, but is deposited directly beneath the cuticula in only the light phase forms.

5. Quantitative determinations were made of carotin present in the grasshopper body by comparing the pigments with a 0.2 per cent potassium dichromate solution in a Bausch and Lomb colorimeter.

6. Carotin was present in a concentration of 0.0436 milligram per gram of body weight in the females; of 0.0397 milligrams per gram of body weight in the males (both determinations with the alimentary canal removed); and of 0.266 milligram per gram of tissue in the reproductive organs and surrounding fatty materials.

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## CONCERNING THE RHOPALIDAE (HEMIPTERA)

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The *Rhopalidae* constitute a more or less homogeneous group of bugs that are set apart from related *Coreoidea* by characters having to do with the repugnatorial glands and their openings. In general the species exhibit remarkable plasticity of structure and great variation in color for which reasons among others their taxonomy is in a somewhat chaotic state. As now understood the family is divisible into four groups of genera or tribes, namely *Harmostini*, *Leptocorini*, *Myrmini*, and *Rhopalini*. These may be separated by the following key adapted from Stål.

### KEY TO THE TRIBES OF RHOPALIDAE

- I. Hind femora prominently spinose within.....*HARMOSTINI*  
Hind femora unarmed or only inconspicuously armed.....II
- II. Hemelytron with vein R joining vein M at or before the origin of  $M_2$ . Cell  $M_1$  roughly triangular. Lateral margin of pronotum interrupted by a distinct notch or constriction just back of collar .....*LEPTOCORINI*  
Corium with vein R joining M distad to origin of  $M_2$ . Cell  $M_1$  (inner apical cell) distinctly quadrangular. Lateral edge of pronotum continuous, straight or slightly sinuate, but not incised before the calli .....III
- III. Body narrow, elongate, the sides somewhat parallel. Head porrect. Antennal segment III longer than IV, I greatly surpassing apex of tylus .....*MYRMINI*  
Body not elongate, not parallel-sided. Head more or less declivent. Antennal segment IV usually longer than III, if shorter than III then I not surpassing tip of tylus.....*RHOPALINI*

The tribe *HARMOSTINI* is composed of four genera, namely *Harmostes* Burmeister, *Aufeuus* Stål, *Xenogenus* Berg, and *Ithamar* Kirkaldy. The latter is Hawaiian, the others American in distribution. The tribe *LEPTOCORINI* is composed of the widely distributed genus *Leptocoris* Hahn and the American genus *Jadera* Stål. Two European genera, *Myrmus* Hahn and *Chorosoma* Schilling, comprise the tribe *MYRMINI*.

The tribe *RHOPALINI* (*Corizini* of authors) is made up of a number of distinct and more or less easily recognized groups, which have, however, been rather generally ignored by American workers. Recently Torre-Bueno has directed attention to the validity of the groups as originally set apart by Stål. My own studies have convinced me of the worth



of Stål's groupings and I find that the genital characters are of the same general type within a group. The question of the rank of these groups is unsettled. Certain of them, for example *Stictopleurus*, *Maccevethus*, *Corizus*, *Rhopalus*, and *Liorhyssus*, clearly are deserving of generic rank. Others I would tentatively assign generic rank until more material from various faunal zones can be had for study and comparison. Surely the problem of the generic relationships within the family ought to be approached from the viewpoint of the worldwide distribution of its included members. One of the first tasks will be to catalog the species and to sort those that stand in *Corizus* sens. lat. It is hoped that the following key and notes will have some worth as an aid in this.

#### KEY TO GENERA OF RHOPALINI<sup>1</sup>

- I. Metastethial orifices well developed, placed low between intermediate and posterior acetabula and giving rise to two short sulci the anterior of which sometimes is obsolete. Metapleuron divided by a vertical furrow into definite anterior and posterior parts, these usually not evenly punctured, the hind margin oblique or concave (except in *Peliochrous*). Transverse furrow or cicatrices of pronotum never ending on each side in a loop inclosing a raised area.....IV
- Metastethial orifices obsolete and indistinct. Metapleuron not or only indistinctly divided into two parts coarsely and evenly punctate, its hind margin approximately perpendicular to the upper margin, the included angle broadly rounded. Pronotum with cicatrices usually ending on each side in a distinct loop in the center of which is a raised calloused island .....II
- II. Antenniferous tubercules truncate at apex. Segment IV of antennae shorter than III. Body narrow, depressed .....  
.....*AGRAPHOPUS* Stål
- Antenniferous tubercules angular or acute at apex. Antennal IV distinctly longer than III .....III
- III. Antennals II and III stout. Lateral edges of pronotum calloused and smooth. Segment VI of abdomen of female above sinuately truncate at apex, not produced outward beyond apex of connexivum. Male clasper very broad and flat, its outer end rounded.....*MACCEVETHUS* Dallas
- Antennals II and III more slender. Side margins of pronotum not calloused. Segment VI of abdomen of female roundly produced at apex above. Male claspers slender or strap-like .....*STICTOPLEURUS* Stål
- IV. Anteocular part of head rather strongly produced, antennal I not nearly attaining apex of tylus. Metapleuron subtruncate behind, the outer hind angle rounded, not produced back-

<sup>1</sup> *Corizomorpha* Jak. (1883) is not included in the key. *Camptonotus* Jak. (1885) belongs to the Lygaeidae.

- wards. Ocelli situated rather close to the eyes.....*PELIOCHROUS* Stål
- Anteocular part of head short or only moderately produced, antennal I sub-attaining or distinctly surpassing apex of tylus. Metapleuron produced backwards at the upper or outer edge, its hind margin oblique or concave. Ocelli about half as far from the eyes as from each other .....V
- V. Pronotum with collar narrow but distinct and sharply delimited, the part between collar and cicatrices forming a distinct ridge which is polished and impunctate.....VI
- Pronotum anterior to cicatrices not smooth and polished, sometimes with a slight transverse ridge which, however, is always punctate on its front margin; the collar not sharply delimited .....VII
- VI. Metapleuron with the anterior part not at all or only indistinctly punctured. Clavus and corium opaque (except in *C. limbatus* Reuter and *C. fenestella* Horvath), punctate throughout. Color usually red and black.....*CORIZUS* Fallen
- Metapleuron thickly, coarsely punctate on anterior part. Clavus and corium in greater part hyaline, punctate only along outer vein .....*LIORHYSSUS* Stål
- VII. Head quite short, scarcely more than half as long as broad. Bucculae high, of about equal height throughout, their posterior ends close to base of head .....VIII
- Head longer, distinctly more than half as long as broad. Bucculae variable in height but usually more or less narrowed posteriorly, not closely approaching base of head .....IX
- VIII. Rostrum short, not or barely attaining metasternum. Antenniferous tubercles small and inconspicuous .....*BRACHYCARENUS* Fieber
- Rostrum attaining middle of metasternum. Antenniferous tubercles strongly produced into long, style-like processes .....*LIMACOCARENUS* Kiritschenko
- IX. Frenum extending at least to apical third of scutellum, the lateral margin of the scutellum sinuate at that point .....X
- Frenum extending only to or just slightly beyond middle of scutellum .....XI
- X. Scutellum with apical part gradually narrowed, almost parallel-sided, the tip truncate, emarginate or bifid. Outer apical cell of corium entirely hyaline.....*RHOPALUS* Schilling
- Scutellum with apical part more sharply narrowed, the tip subacute. Outer apical cell (Sc) of corium in part coriaceous and punctate .....*AESCHYNTELUS* Stål
- XI. Rostrum extending on or beyond second segment of venter. Femora annulose .....*NIESTHREA* Spinola
- Rostrum not or rarely reaching behind metasternum. Femora sometimes speckled but not clearly annulose....*ARHYSSUS* Stål

*Corizus* Fallen

- 1814 *Corizus* Fallen, Spec. Nova Hemip. Disp., p. 8.  
 1835 *Corizus* Brullé, Hist. des Ins., Hemip., p. 116.  
 1840 *Corizus* Westwood, Intro. Mod. Classif. Ins., 1, Synop. p. 123.  
 1843 *Therapha* Amyot et Serville, Hist. Nat. des Ins., Hemip., p. 244.  
 1885 *Corinzus* Reuter, Berl. Ent. Zeit., 29: 42.  
 1888 *Corizus* Reuter, Acta Soc. Sci. Fenn., 15: 270, 759.  
 1909 *Consivius* Distant, Ann. Mag. Nat. Hist., (8) 3.  
 1917 *Corizus* Horvath, Ann. Mus. Nat. Hung., 15: 166, 379.

Fallen established *Corizus* for a portion of the species treated under *Coreus* in his earlier Monographia Cimicum Sueciae and specifically stated that it was divisible into two sections. To the first he referred *crassicornis* (L.), *capitatus* (Fabr.), *pratensis* Fallen, and *miriformis* Fallen. To the second division he referred the single species, *hyoscyami* (L.). Reuter thought that in thus setting *hyoscyami* apart from the other species Fallen recognized it as the typical species (cf. Revisio, p. 270). Other workers (e.g., Distant and Oshanin) considered other species as type of the genus and some controversy arose which was settled only by the discovery that Brullé, in 1835, had designated *hyoscyami* as type species. The problem was of considerable interest inasmuch as the generic name to be applied to the common species in Europe and also in America as well as the name of the family hinged upon its solution.

*Therapha* was erected for two species, *T. cinerea* A. and S. and *T. hyoscyami* (L.). When the former was referred to *Jadera*, the latter therefore became the only included species and thus type of *Therapha* which then is an absolute synonym of *Corizus* Fallen.

*Consivius* Distant was erected for a single species, *collinus* Distant, which is congeneric with *Corizus hyoscyami* (L.) and according to Horvath only a variety of that species.

Seventeen species and varieties are now referred to *Corizus*. The genus does not occur in the Western Hemisphere.

*Rhopalus* Schilling

- 1827 *Rhopalus* Schilling, Uebers. Arb. Ver. Schleis. Ges. V. Cultur, p. 22.  
 1829 *Rhopalus* Schilling, Beitr. Zur. Ent., 1: 36, 50.  
 1840 *Rhopalus* Westwood, Intr. Mod. Classif., Ins., 2, Synop., p. 123.  
 1843 *Rhopalus* Amyot and Serville, Hist. Nat. Ins., Hemip., p. 245.  
 1885 *Rhopalus* Reuter, Berl. Ent. Zeit., 29: 42.  
 1888 *Rhopalus* Reuter, Acta Soc. Sci. Fenn., 15: 270, 767.  
 1917 *Rhopalus* Horvath, Ann. Mus. Nat. Hung., 15: 380.

*Rhopalus* has usually been dated from 1829 but actually was validated in 1827 in the work cited above where, in the general report on the hemiptera is stated, "Herr Schilling theilte de Beischreibung der in Schlesien ein heimischen Arten aus der Gattung *Coreus* mit, worunter vier neue Arten sich befanden, *C. marginellus*, *spinifrons*, *laticornis*, und

*granulatus*. Aus *Coreus crassicornis*, *capitatus*, und *ihrlichen*, wurde eine neue Gattung, *Rhopalus*, gebildet —." In his Hemiptera Heteroptera Silesiae, 1829, Schilling characterized *Rhopalus* and included in it his third group of "coreides", i.e., those with branching nervures in the membrane, triangular head, antenniferous tubercle inserted before the eyes, and diaphanous hemelytra with stout veins and a quadrate inner distal cell. To illustrate the character of the hemelytra he made reference to his Table II, Figure 4 (which is a figure of *R. tigrinus* Schill.). On p. 50 Schilling further characterized the genus by describing the genital segments, following which he treated 7 species. These were *R. crassicornis* Fabr. (which is figured), *R. capitatus* (Fabr.), *R. rufus* Schill. (as new species for *Coreus capitatus* Panzer nec Fabr.), *R. parumpunctatus* Schill. (as new species for *Coreus magnicornis* Fall. nec L.), *R. tigrinus* Schill., *R. miriformis* Schill., and *R. schillingi* (Schm.) Schill. These last two named species are set apart from the others by their elongate body. No species is designated as type.

In 1840 Westwood designated *capitatus* Wolff as type of *Rhopalus* (note: Schilling cited *Lygaeus capitatus* Wolff in synonymy with *Coreus capitatus* Fabr.). Amyot and Serville dealt with only one species (*capitatus*), but I think in no sense can it be said that they designated a genotype for *Rhopalus*, although some workers seem to think that they did. Reuter (1885 and 1888) was emphatically of the opinion that Schilling established *tigrinus* as type of *Rhopalus* when in the generic characterization Schilling referred to his Table II, Figure 1. Oshanin followed Reuter in this assumption, but it appears to me that Schilling was only clarifying, through illustration, his comments on the nature of the hemelytron. This most certainly was the case when earlier on the same page he said of his first group of the coreides, "Membrana nervis ramosis (Table II, Fig. 2)." Reuter was therefore in error, I think, in interpreting this as indicating a genotype. In any case Reuter was not aware of the 1827 use of *Rhopalus*, and if the genus were validated at that time, as I consider that it was, then *tigrinus* is not available for consideration as type since it was not one of the 1827 included species. Therefore, Westwood's designation of *capitatus* Wolff, 1802 (*capitatus* Fabr., 1775; = *subrufus* Gmelin, 1788), is the first valid designation of a genotype for *Rhopalus* Schilling.

In the sense here used, *Rhopalus* consists of a number of species grouped around *subrufus* (Gmelin), *conspersus* (Fieber), *rufus* Schill., *parumpunctatus* Schill., and *lividus* (Ribaut).

#### Genus *Niesthrea* Spinola

- 1811 *Coryna* Wolff, Icon. Cimic., 5: p. iv.
- 1837 *Niesthrea* Spinola, Essai sur les Hemip., p. 245.
- 1870 *Niesthrea* Stål, Kongl. Sv. Vet.-Akad. Handl., 9: 223.
- 1908 *Niesthrea* Baker, Can. Ent., 40: 243.
- 1941 *Niesthrea* Torre-Bueno, Ann. Ent. Soc. Amer., 34: 286.

Elsewhere I have shown that *Coryna* Wolff (haplotype, *Lygaeus sidae* Fabr.), is unavailable for use. It therefore is replaced by *Niesthrea* Spinola, haplotype *Coreus sidae* (Fabr.). The group appears to be strictly American.

#### Genus *Maccevethus* Dallas

- 1852 *Maccevethus* Dallas, List. Hemip. Br. Mus., 2: 520, 524.
- 1872 *Maccevethus* Stål, Ofv. Kongl. Vet.-Akad. Forh., 29: 55.
- 1912 *Maccevethus* Oshanin, Kat. Pal. Hemip., p. 26.
- 1917 *Maccevethus* Horvath, Ann. Mus. Nat. Hung., 15: 380.

The name *Maccevethus* was used by Amyot in 1846, but in a monomial sense, and was taken over by Dallas when he created this genus for *Lygaeus errans* Fabr., 1794. Ten names have been used in the genus, but six of these, including *errans*, are now considered as synonyms or at most only varieties of the older *M. lineola* (Fabr.). Structurally the group is close to *Stictopleurus* Stål. In *lineola* the male claspers are broad and flat. Haplotype, *Lygaeus errans* Fabr., 1794 (= *Cimex lineola* Fabr., 1787).

#### *Brachycarenum* Fieber

- 1861 *Brachycarenum* Fieber, Europ. Hemip., p. 60, 236.

This group name was established as a genus for the *haplotype*, *Rhopalus tigrinus* Schill., and was later placed in synonymy by Reuter who erroneously held that *tigrinus* was the genotype of *Rhopalus*. In addition to *tigrinus*, *languidus* Horvath belongs to the genus.

#### Genus *Liorhyssus* Stål

- 1870 *Liorhyssus* Stål, Enum. Hemip., 1: 222.
- 1872 *Liorhyssus* Stål, Ofv. Vet.-Akad. Forh., 29: 55.
- 1870 *Colobatus* Mulsant and Rey, Hist. Punaise de Fr., 3: 137.
- 1873 *Liorhyssus* Stål, Kongl. Sv. Vet.-Akad. Handl., 11: 97.
- 1908 *Liorhyssus* Baker, Can. Ent., 40: 243.
- 1912 *Liorhyssus* Oshanin, Kat. Palae. Hemip., p. 25.
- 1941 *Liorhyssus* Torre-Bueno, Ann. Ent. Soc. Amer. 34: 286.

Stål created *Liorhyssus* in 1870 as a subgenus of *Corizus* Fallen and referred 7 species to it. Two years later he accredited generic rank to the group and cited *Colobatus* M. and R. in synonymy. Oshanin (1912) made *hyalinus* (Fabr.) type. At least 28 names are referrable to *Liorhyssus* but these are mostly synonyms and only color varieties of the almost cosmopolitan *L. hyalinus* Fabr. The name is derived from the Greek and is descriptive of one of the main recognition features, i.e., the *smooth ridge* across the front of the pronotum.

#### *Arhyssus* Stål

- 1870 *Arhyssus* Stål, Kongl. Sv. Vet.-Akad. Handl., 9: 223.
- 1908 *Arhyssus* Baker, Can. Ent., 40: 244.



1917 *Arhyssus* Van Duzee, Cat. Hemip., p. 124.

1941 *Arhyssus* Torre-Bueno, Ann. Ent. Soc. Amer., 34: 286.

The group name *Arhyssus* was created by Stål for three American species, *Rhopalus punctiventris* Dallas, *Corizus bohemani* Signoret, and *Rhopalus scutatus* Stål. The first is a true *Stictopleurus* and there is no basis for Baker's statement that Stål made it type of *Arhyssus* except that it was the first species in Stål's list. Van Duzee named *bohemanii* logotype. The species apparently are confined to the Western Hemisphere.

### *Aeschyntelus* Stål

1872 *Aeschyntelus* Stål, Ofv. Kongl. Vet.-Akad. Forh., 29: 55.

1888 *Aeschynteles* Reuter, Acta Soc. Sci. Fenn., 15: 757.

*Aeschyntelus* was established as a subgenus of *Rhopalus*, for the two species, *maculatus* Fieber and *parumpunctatus* Schill. Reuter designated *maculatus* type. It appears to me that *parumpunctatus* is sufficiently different from *maculatus* and sufficiently close to *Rhopalus subrufus* (Gmelin) and *R. rufus* Schill. to warrant being included in *Rhopalus*. I should redefine *Aeschyntelus* to include those species having triangular tip of scutellum and having the coriaceous part of the hemelytra encroaching inward beyond the Sc vein so that the outer apical cell is coriaceous and colored in part. These species also have fine clothing hairs, those on the tibia being long and pale. In addition to *A. maculatus* (Fieber), *A. latus* (Jak.) belongs here, also *A. angularis* Reuter and *A. reuteri* L. and S. and undoubtedly some of the other described species that are still unknown to me.

### Genus *Stictopleurus* Stål

1872 *Stictopleurus* Stål, Ofv. Vet.-Akad. Forh., 29: 55.

1873 *Stictopleurus* Stål, Kongl. Sv. Vet.-Akad. Handl., 11: 98.

1908 *Corizus* Baker, Can. Ent., 40: 242.

1912 *Stictopleurus* Oshanin, Kat. Palae. Hemip., p. 25.

1917 *Stictopleurus* Horvath, Ann. Mus. Nat. Hung., 15: 380.

1941 *Stictopleurus* Torre-Bueno, Ann. Ent. Soc. Amer., 34: 285.

Stål erected *Stictopleurus* for *crassicornis* (L.) and *abutilon* Rossi and in a footnote mentioned *scutellaris* Dallas. Oshanin designated *crassicornis* type of the genus. Ribaut's excellent work demonstrated the worth of the genital characters in distinguishing the species, and China has given a key to the Western European forms. In attempting to catalogue the species I have tentatively referred 45 names to *Stictopleurus*. Many of these were established in *Corizus* or *Rhopalus*, and the synonymy is not worked out. The common American species which has gone under the name *crassicornis* (L.) is quite distinct from that European species. For this American species the name *punctiventris* (Dallas) is available. Logotype: *Cimex crassicornis* L.



Genus *Agraphopus* Stål

- 1872 *Agraphopus* Stål, Ofv. Kongl. Vet.-Akad. Forh., 29: 56.  
 1874 *Leptoceraea* Jakovlev, Trudy Ent. Ross., 7: 38.  
 1894 *Agraphopus* Lethierry and Severin, Cat. Gen. Hemip., 2: 121.  
 1912 *Agraphopus* Oshanin, Kat. Palae. Hemip., p. 26.  
 1917 *Agraphopus* Horvath, Ann. Mus. Nat. Hung., 15: 380.

This genus was created for *Agraphopus lethierryi* Stål which is thus the haplotype. *Leptoceraea* Jakovlev, type *viridis* Jak., is a synonym. Twenty-two species and subspecies are recorded from Europe, Russia, Asia, Africa, Madagascar, and S. India.

*Peliochrous* Stål

- 1873 *Peliochrous* Stål, Kongl. Sv. Vet.-Akad. Handl., 11: 97.

This group name was created by Stål for the haplotype, *P. nigromaculatus* (Stål), from Africa. It is said to be distinct generically by reason of the long head, the widely separated ocelli which are close to the eyes, the absence of a smooth ridge across front of pronotum, and the characters of the metapleuron and genital segments.

*Corizomorpha* Jakovlev

- 1882 *Corizomorpha* Jakovlev, Bull. Soc. Nat. Moscow, 57 (2): (3) 107.  
 1912 *Corizomorpha* Oshanin, Kat. Palae. Hemip., p. 25.

This genus was established for the haplotype, *C. janowskyi* Jak. It is said to be distinct by virtue of the long, flattened form, the head and scutellum being longer than broad, and by the characters of the legs, antennae, pronotum, and abdomen.

*Limacocarenum* Kiritshenko

- 1914 *Limacocarenum* Kiritshenko, Revue Russe d'Ent., 13: 402 (1913).  
 1914 *Scolopocranium* Horvath, Ann. Mus. Nat. Hungarici, 12: 659.

This genus was erected for a single new species, *curtulus* Kiritshenko, from Turkestan and is unknown to me. It is reported to differ from related genera in its short and broad head, high, long bucculae, greatly produced antenniferous tubercles, and in the characters of the metapleuron, eyes, and rostrum. It would be very interesting to examine specimens of the haplotype since the American species *Arhyssus tuberculatus* (Hambleton) has greatly produced antenniferous tubercles. *Scolopocranium* Horvath was proposed as a name to replace *Limacocarenum* but must stand as a synonym of Kiritshenko's genus.

# HOST AND SEASONAL NOTES ON THE RABBIT TICK, *HAEMAPHYSALIS LEPORIS-PALUSTRIS*<sup>1</sup>

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Observations on the host preferences and seasonal abundance of the rabbit tick, *Haemaphysalis leporis-palustris*, were made by the authors during the summer and fall of 1941. This paper deals specifically with such findings. Since 20.8 per cent of all ticks collected during the course of the studies were the rabbit tick, that species proved to be second in abundance to the dog tick. The data concerning the rabbit tick was obtained during an intensive field study and survey of ticks on the Tama Indian Reservation, Tama, Iowa. Information relative to the host preferences and seasonal biology of the dog tick, *Dermacentor variabilis*, and a list of the ticks of Iowa will appear in other papers. A preliminary report of the tick studies was made by the authors in July, 1941 (Eddy and Joyce).

Due to the importance of rabbit ticks as vector of diseases of man and other animals it was thought advisable to gather more information concerning this species in Iowa. Parker (1923) has shown that this tick may be naturally infected with Rocky Mountain spotted fever in Montana and that, experimentally, the disease can be readily transmitted from one rabbit to another. Parker, Spencer, and Francis (1924) have shown that this tick transmits tularemia and is probably an important factor in maintaining the reservoir of tularemia and spotted fever in rabbits and other small rodents.

Dr. Carl F. Jordan, State epidemiologist of Iowa, has reported 342 human cases of tularemia in Iowa in the period from 1930 to 1939. From 1933 to 1940, 85 cases of spotted fever were reported. Since the rabbit tick does not readily attach itself to man it cannot be considered an important vector for human cases of these diseases. *H. leporis-palustris* is thought to be of importance, however, in keeping these diseases alive in nature. During the spring and early summer large numbers of both the rabbit tick and the common dog tick were found on the same cotton-tails. The latter species has been shown to be a carrier of tularemia and spotted fever to man. Tularemia is thought to be the most common epi-

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TABLE 1  
COLLECTIONS OF THE IMMATURE FORMS OF THE RABBIT TICK FROM BIRDS IN THE TAMA VICINITY

Common Name	Host	Scientific	No. EXAMINED	No. POSITIVE	No. NYMPHS	No. LARVAE
Brown thrasher.....		<i>Toxostoma rufum</i> .....	24	23	154	1957
Wren.....		<i>Troglodytes aedon</i> .....	14	14	2	128
Blue jay.....		<i>Cyanocitta cristata cris.</i> .....	12	4	2	30
American robin.....		<i>Turdus migratorius migr.</i> .....	11	7	11	92
*Indigo bunting.....		<i>Passerina cyanea</i> .....	7	6	1	41
Catbird.....		<i>Dumetella carolinensis</i> .....	10	6	3	27
Red-eyed towhee.....		<i>Pipilo erythrophthalmus ery.</i> .....	5	5	6	53
*Rose-breasted grosbeak.....		<i>Hydymelus ludovicianus</i> .....	9	5	4	27
Cardinal.....		<i>Richmondia cardinalis car.</i> .....	9	4	6	15
Ovenbird.....		<i>Seiurus aurocapillus</i> .....	3	3	1	46
Olive-back thrush.....		<i>Hylocichla ustulata swainsoni</i> .....	3	3	2	27
Junco.....		<i>Junco hyemalis hye.</i> .....	7	2	2	44
*Grasshopper sparrow.....		<i>Ammodramus savaamarum bimaculatus</i> .....	5	2	1	3
*Domestic chicken.....		<i>Gallus gallus</i> .....	27	2	4	0
*Flicker.....		<i>Colaptes auratus</i> .....	7	2	1	6
*Bluebird.....		<i>Sialia sialis sialis</i> .....	4	2	0	2
Quail.....		<i>Colinus virginianus vir.</i> .....	3	1	14	0
Pheasant.....		<i>Phasianus colchicus torquatus</i> .....	2	1	0	8
American redstart.....		<i>Setophaga ruticilla</i> .....	1	1	0	2
Tufted titmouse.....		<i>Baeolophus bicolor</i> .....	1	1	0	2
Field sparrow.....		<i>Spizella pusilla pus.</i> .....	5	1	0	3
*Black-capped chickadee.....		<i>Parus atricapillus atr.</i> .....	10	1	0	11
Fox sparrow.....		<i>Passerella iliaca iliaca</i> .....	8	1	0	16
*Hairy woodpecker.....		<i>Dryobates villosus vil.</i> .....	1	1	1	9
American crow.....		<i>Corvus brachyrhynchos brac.</i> .....	2	1	1	0
*Dickcissel.....		<i>Spiza americana</i> .....	1	1	0	1
*Black-billed cuckoo.....		<i>Coccyzus erythrophthalmus</i> .....	2	1	0	1
*Eastern kingbird.....		<i>Tyrannus tyrannus</i> .....	5	1	0	1
American goldfinch.....		<i>Spinus tristis tristis</i> .....	9	1	0	1
Totals.....			207	107	218	2553

\* Denotes new host records

demic disease in rodents and birds. In addition to the possibility of disease transmission the rabbit tick is a pest due to its blood-sucking habit which greatly irritates the animals infested. Often many thousand ticks are found on a single animal. Banks (1915) reported that quail and meadow-larks are sometimes killed by the rabbit tick.

#### HOSTS

The chief hosts of *H. leporis-palustris* are the various species of rabbits and hares. The tick may rarely be found attached to other species of mammals. It seldom attaches to man. Other hosts mentioned in the literature are the following: horse, cat, dasyure, pine squirrel, skunk, ground hog, and chipmunk. Birds play a very important role as host for the immature forms of the rabbit tick. This fact may to a great extent explain the widespread distribution and dissemination of this tick. The tick has been recorded many times from meadowlarks, robins, quail, and numerous other ground-feeding birds. Peters (1936) records its collection from a list of 46 species of birds, in connection with his bird banding studies.

The accompanying list (Table 1) of collections of *H. leporis-palustris* represents the bird hosts of this tick on the Tama Indian Reservation. Those marked with an asterisk are apparently new host records. Two hundred sixty-six individual birds comprising 56 species were examined during the course of the studies. The 29 species listed in the table are only those from which ticks were removed. Many birds of some of the other species were examined, but no ticks were found upon them. The bird families of most importance as hosts for the rabbit tick, as evidenced by the number of ticks obtained, are as follows: *Mimidae* or thrasher family, *Fringillidae* or sparrow family, *Turdidae* or thrush family, and *Troglodytidae* or wren family. Ten of the species listed belong to the *Fringillidae* or sparrow family. From the list one can see that most of the bird species that serve as host for the rabbit tick are ground-feeding. They naturally have more of a chance of picking up the tick. It is interesting to note that all 2,772 (including the one adult mentioned later) of the ticks taken from birds were of the one species. The dog tick was evidently more abundant in the area, but the immature stages of that tick do not seem to commonly attach themselves to birds. Peters (1936), however, does give four records of the dog tick from birds.

The brown thrasher appears to be the one most important bird host of the rabbit tick. Two thousand one hundred eleven ticks were removed from 24 brown thrashers. From one bird, obtained on July 19, 495 ticks were removed. The following table is a summary of the collections from the brown thrasher.

The Indian Reservation is comprised mostly of rather rough terrain along the Iowa River. A large part of the land is timber or brush land. There are also several weedy areas and a small portion is in farm crops. The area thus makes a very good habitat for birds. Many species were present in this area. In some other localities other bird species will possibly be found to harbor the rabbit tick. In more grassy areas and on land

TABLE 2  
*H. leporis-palustris* FROM BROWN THRASHER

Month	No. Birds Examined	Ave. Nymphs Per Bird	Ave. Larvae Per Bird	Per Cent Infested
April.....	2	2.00	3.00	100
June.....	1	0.00	0.00	0
July.....	7	14.14	105.71	100
Aug.....	4	3.00	125.50	100
Sept.....	10	3.90	70.90	100
Total Ave. Mean...	24	6.41	81.54	95.8

where more farming is done, the meadowlark, quail, pheasant, and other ground-feeding birds may be of more importance in the life history of the tick.

The Mearns cottontail is the normal host of *H. leporis-palustris* in this locality. The tick very rarely attaches itself to other mammals. Such records are thus considered "accidental." A very large number of animals were examined in the studies on the dog tick, but the records listed below are the only occurrences of the rabbit tick on these animals.

TABLE 3  
IMMATURE FORMS OF *H. leporis-palustris* FROM MAMMALS

Common Name	Scientific Name	No. Positive	Nymphs	Larvae
Cottontail.....	<i>Sylvilagus floridans mearnsi</i>	56	610	861
Ground hog.....	<i>Marmota monax</i>	1	0	10
House cat.....	<i>Felis domestica</i>	1	0	2
*Dog.....	<i>Canis familiaris</i>	1	0	1
*Opossum.....	<i>Didelphis virginiana virginiana</i>	1	0	1
Totals.....	.....	60	610	875

\* Denotes new host records.

The cottontail rabbit seems to be almost the sole host for the adult stages of the rabbit tick although one male specimen was taken from a robin in July. Possibly adults would have been taken from other birds if more had been examined earlier in the spring when adults were more abundant. Two hundred twenty-two male and 78 female adult specimens were taken from the cottontail.

#### SEASONAL STUDIES

Since the population of cottontails on the reservation was low and the cover on the area was dense, it was hard to collect enough rabbits to furnish an accurate gauge of the degree of tick infestation. A few rabbits were shot each month, however, and the data summarized in the accompanying table (Table 4). The collections in the Tama vicinity were made from April 16, 1941, to December 23, 1941. A total of 56 rabbits were taken during the period. From these rabbits 1,771 rabbit ticks were re-

moved. The ticks are nearly all found attached around the head, neck, and ears of the animal. The animals were shot in the field, placed in a paper bag, and taken in to the laboratory for examination. When the animal becomes cold the ticks detach and crawl away.

Cooley (1932) states that the rabbit tick is not a winter feeding species in the northern states and that the species hibernates between active seasons. Green, Bell, and Evans (1938) report that in Minnesota the rabbit tick emerges from hibernation during the first part of April and continues to be active through the month of November. They show August and September to be the period of peak abundance. In the South it has been reported by Hooker, Bishop, and Wood (1912) that all stages are active throughout all seasons of the year. There is, however, a decrease in abundance during the winter months. In Oklahoma, Eddy (1940) reports that the larvae and nymphs are active during all months of the year. He reports no males in December and no females in November.

The collections by the authors on the Tama Indian Reservation show that the adults are active throughout the spring and summer. April and May are the high months for the adults. The numbers then gradually dwindle down to a very few in August and only one male specimen in September. The larvae and nymphs were much more abundant throughout the year up to the month of December. No rabbit ticks of any stage appeared to be active during the month of December. June, July, and August were the months of greatest abundance for the immature forms. The data obtained, however, were insufficient to show quantitative accuracy. The accompanying table and graph (Table 4 and Fig. 1) summarize the nine months' collecting of *H. leporis-palustris* from the cottontail. Later collections by the authors at Ames, Iowa, in the spring of 1942 show that all stages of the rabbit tick become active during the last week of March or the fore part of April. March 24 was the earliest date on which ticks were removed from a cottontail.

TABLE 4

RECORD OF NINE MONTHS' COLLECTION OF THE RABBIT TICK, *Haemaphysalis leporis-palustris*, FROM THE MEARNS COTTONTAIL AT TAMA, IOWA

Month	No. Rabbits	Ave. Males Per Rabbit	Ave. Females Per Rabbit	Ave. Nymph Per Rabbit	Ave. Larvae Per Rabbit	Total Ave.
April.....	13	8.46	2.23	11.23	1.77	23.69
May.....	10	7.80	3.60	11.40	1.30	24.10
June.....	5	3.60	1.80	15.20	3.00	23.60
July.....	4	3.00	.75	4.25	12.25	20.25
Aug.....	5	.60	.20	16.60	105.40	122.80
Sept.....	5	.20	.00	7.20	41.40	48.80
Oct.....	2	.00	.00	64.50	11.50	76.00
Nov.....	6	.00	.00	1.50	.66	2.16
Dec.....	6	.00	.00	.00	.00	.00
Total Ave. Mean..	56	3.96	1.39	10.89	15.38	31.62



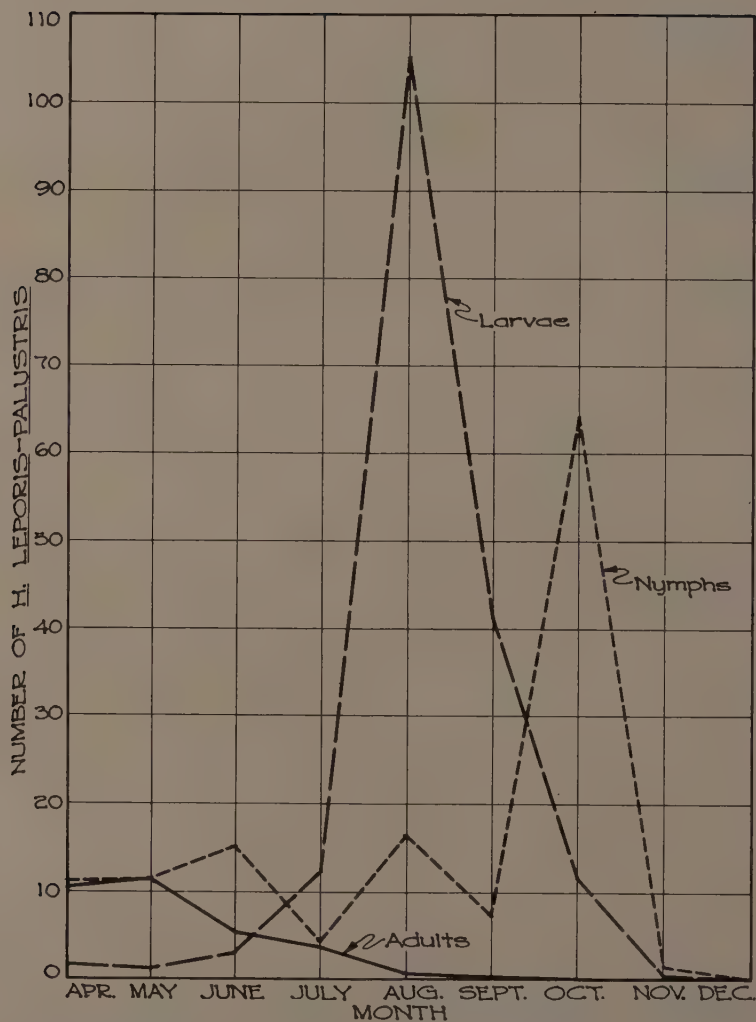


FIG. 1. Seasonal trend. Average number of *H. leporis-palustris* per cotton-tail, April to December, 1941.

## PARASITES

Due to the important role of ticks as vectors in several diseases there has been considerable interest in the discovery of parasites as means of control. Only two parasites of ticks are known. These are minute *Chalcidoids* belonging to the family *Encyrtidae*. They are *Ixodiphagus texanus* and *Hunterellus hookeri*, which were described by Howard in 1907 and 1908, respectively.

During the summer a special search was made for any parasite which might be found infesting the various species of ticks in the collections made on the reservation. The engorged females, nymphs, and many of the engorged larvae were placed in vials, stoppered with cotton, and set in a moist chamber for molting or for the possible emergence of parasites.

The authors report the isolation of *Ixodiphagus texanus* from the rabbit tick. On April 24, 1941, a fully engorged nymph of *H. leporis-palustris* was taken from a brown thrasher and set aside for further development. Some time later 14 specimens of the hymenopterous parasite emerged from an opening near the posterior end of the nymph. These were identified as *Ixodiphagus texanus* Howard. This is apparently the first record of a tick parasite from Iowa. Only a few isolations have been made throughout the United States. Bishopp (1934) records it from nymphs of *H. leporis-palustris* from a chapparral cock at Reagan Wells, Texas. Cooley (1934) reports its natural occurrence in nymphs of *Ixodes hexagonus* var. *cookei* on a woodchuck in Mayfield, Idaho. Larson (1937), and Larson and Green (1938) show the parasite to be widely distributed in Minnesota. They found that only 5.7 per cent of the tick nymphs and larvae were parasitized. The parasite was not considered of very great significance in the control of ticks in the area in which they conducted their studies.

## SUMMARY

In studies made on the Tama, Iowa, Indian Reservation from April 16 to December 23, 1941, the rabbit tick, *Haemaphysalis leporis-palustris* was found to be second in abundance to the dog tick, *Dermacentor variabilis*. Twenty and eight-tenths per cent of all ticks collected were the rabbit tick. Many of the common ground-feeding birds were found to be very important as hosts for the immature forms of this tick. Twenty-nine bird species from which ticks were removed are listed. Of these, 11 are apparently new host records. A table, showing the seasonal trend, is given of 9 months' collection of the rabbit tick from the Mearns cottontail taken from the Tama vicinity. The isolation of the tick parasite, *Ixodiphagus texanus*, is also reported from a nymph of *H. leporis-palustris* at Tama, Iowa.

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# THE RESPONSE OF SOME FIELD CROPS ON SOIL TREATED WITH CHLORPICRIN<sup>1</sup>

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The soil-inhabiting plant pathogens *Pythium debaryanum* Hesse and *P. graminicola* Subr. are widely distributed and destructive root parasites in Iowa soils. These pathogens frequently destroy the seeds, kill the seedlings, or severely injure the roots of older plants. The direct control of these pythiaceae parasites requires some soil treatment that will destroy the pathogens. Chlorpicrin recently has shown some value as a soil fumigant for several soil-inhabiting pathogens, such as *Plasmodiophora brassica* Wor., *Rhizoctonia solani* Kühn, *Sclerotium rolfsii* Sacc., *Verticillium albo-atrum* McA., *Armillaria mellea* (Vahl.) Quel., etc., which occur on eggplants, peppers, tomatoes, onions, rutabagas, carrots, and others. No study has been made, however, of its value in combatting pythiaceae parasites that attack the cereal and forage crops grown in the Upper Mississippi Valley. It is the purpose of this paper to present the results obtained with oats, barley, wheat, flax, sugar beets, alfalfa, rye, and cowpeas grown on *Pythium*-infested soils and upon similar soils that had been treated with chlorpicrin.

## PERTINENT LITERATURE

The value of chlorpicrin as a soil fumigant has not been studied very extensively. As a result, its role in the soil is not well understood.

Cooke (2) believed the action of chlorpicrin to be biological rather than chemical and ran the following tests to ascertain this fact: pH test, citric soluble  $P_2O_5$  and  $K_2O$  test, Hance-Agee test for phosphate fixation, Morgan's active aluminum test, Morgan's  $NO_3/N$  test, Morgan's ammonia-nitrogen test, and Bouyoucos' hydrometer test for percentage colloids. In none of these tests was there a noticeable change caused by the action of chlorpicrin. Cooke also found that soils high in phosphorus content showed practically no improvement from treatment with chlorpicrin, that respiration tests showed that more  $CO_2$  was given off by the nontreated soil than by the treated soil, and that high application of  $P_2O_5$  gave as good yields of sugar cane as did chlorpicrin treatment when used as a control for *Pythium aphanidermatum* (Eds.) Fitzp.

Stark (8) reported that chlorpicrin increased seedling stands, left no residue, and had a stimulatory effect on plants. Howard (5) confirmed Cooke, stating that increase in plant development was not due to added nutrients but primarily to overcoming soil-harbored microorganisms. He

<sup>1</sup> Journal Paper No. J-1015 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 432.

maintained that chlorpicrin was volatile and left the soil, and still further, that the nitrogen in chlorpicrin is in an unavailable form and is supplied in too small amounts to account for the striking increases in growth. Supplementary weekly determinations of the  $\text{NO}_3/\text{N}$  (nitrate nitrogen) ratio in chlorpicrin-treated soil showed it to contain from 10 ppm. to 30 ppm. of  $\text{NO}_3/\text{N}$  less than the nontreated soil, which contained 30 to 40 ppm. He found that tomato plants would grow in treated soil low in nitrates 3 to 4 times as well as in nontreated soil.

In a later study Stark *et al.* (10) found that traces of chlorpicrin in the soil solution were detrimental rather than stimulative to plant growth. These same authors (9) reported that low dosages of chlorpicrin had little effect on nitrate formation but that as the dosage was increased nitrification was inhibited, that the total amount of nitrogen made available for plant growth was not materially increased except where high dosages of chlorpicrin were used, and that in no case tried was ammonification inhibited.

Chlorpicrin has been shown to have a strong lethal effect on several pathogens. Godfrey (4) found that  $1\frac{1}{4}$  cc. of chlorpicrin in a 4-gallon jar of soil (400 lbs. chlorpicrin per A.), sealed with glue-coated paper destroyed *Fusarium* sp. isolated from gladiolus, *Verticillium albo-atrum* from strawberry, *Phytophthora cactorum* (L. and C.) Schröt. from snapdragons, *Rhizoctonia solani* and *Sclerotium rolfsii* from sugar beets, *Armillaria mellea* from prune roots, and *Dematophora* sp. from apple roots. Godfrey found that, although the *Phytophthora cactorum* culture listed above was killed, contaminating bacteria in the culture were not killed. Newton *et al.* (7) conducted preliminary tests which showed that a concentration of 1:195,000 destroyed the vegetative stages of *Fusarium conglomerans* var. *callistephi* Beach, *F. bulbigenum* Cke. and Mass., *F. graminearum* Schwabe, *F. culmorum* Smith, *Botrytis tulipae* (Lib.) Hopk., *Sclerotium delphinii* Welch, and *Phomopsis* sp. They also found that resting sclerotia required high concentrations for an effective kill. Clayton *et al.* (1) working with *Thielaviopsis basicola* (Berk.) Ferraris and *Heterodera marioni* (Cornu) Goodey in tobacco plant beds, reported that compared with steam-pan sterilization, a combination chemical treatment of 1 lb. cyanamid and 36 cc. chlorpicrin per sq. yd. was slightly inferior in weed control and somewhat superior in disease control. Dimock (3) found that either steam or chlorpicrin treatments of soil heavily infested with *Rhizoctonia* sp. gave good control of the *Rhizoctonia* foot-rot of *Matthiola incana* (Annual Stocks). McCulloch (6) reported that plots of *Fusarium*-infested soil treated with chlorpicrin gave results comparable with the check plots of steam sterilized soil and were 50 to 100 per cent better than the plots of nontreated *Fusarium*-infested soil.

#### MATERIALS AND METHODS

Similar experiments were carried out on the experimental farms at Kanawha and Conesville, Iowa. On each farm a plot 30 feet by 40 feet was plowed once, disked twice, leveled with a harrow, and then treated with

chlorspicrin at the rate of 3 cc. per injection at staggered 12-inch intervals 480 lbs. per A.). The chlorspicrin was applied with the Larvajector senior, type C, applicator. The plot at Kanawha, upon which an oat crop was produced in 1940, was located on black, heavy (Clarion loam) soil. It was treated September 20, 1940, and watered immediately for a water seal. The plot at Conesville, upon which a crop of cowpeas was produced in 1940, was located on a light (Buckner) sandy soil. It was treated September 13, 1940, watered immediately for a water seal, watered again after a lapse of 5 hours and again after a period of 12 hours. At the time of the third application of water, chlorspicrin fumes were prevalent enough above the treated area to be readily detected. These treated plots were exposed to the elements for the duration of the winter.

The planting plans of the plots were similar. Seed used in the plantings were surface treated with 5 per cent Clorox solution for 15 minutes and rinsed in water. The tools used in the planting of the plots were dipped into a 5 per cent solution of formaldehyde for 15 minutes before using. The laborer doing the actual plot work wore rubber boots that had been dipped into the formaldehyde solution for 15 minutes before using. Stakes used in marking the plots were dipped into the formaldehyde solution for 30 minutes. Every effort was made to prevent recontamination of the plots in the spring during the process of planting.

Plantings were made on two different dates at each location: at Conesville, April 9 and 25; at Kanawha, April 16 and May 2. The rates of planting per 8-foot row were as follows: oats, wheat, rye, and barley, 100 kernels; flax and alfalfa, 1 gram of seed; cowpeas, 50 seeds; and sugar beets, 100 seed balls.

Check plots identical in arrangement and time of planting were planted adjacent to each of the respective treated areas.

Stand counts in each 8-foot row were made on two dates. All counts made for one particular crop on one date were combined, e.g., the barley counts in the first planting on treated soil at Conesville were 80, 84, 92, 83, 91, and 85, or a total of 515 plants.

At the time stand counts were taken, seedlings were dug from special adjacent rows, examined for disease symptoms, and isolations made. These rows were planted especially for the purpose of furnishing plants for examination. When it was decided that examinations were no longer profitable, the plants in these special rows were cut off and removed from the plots.

At Conesville the crops were harvested July 15, when the small grain crops appeared mature. The first planting at Kanawha was harvested on July 11, the second planting on July 24. All the crops, with the exception of the sugar beets, were harvested by cutting off the plants just above the ground line. The sugar beets were dug from the soil. Immediately after harvesting the plants, green weights were taken, and after a period of 10-14 days, dry weights. Yield data in grams were obtained for oats, wheat, barley, and flax.



## EXPERIMENTAL RESULTS

The results obtained from the early planting at Conesville appear in Table 1. Seedling stand counts showed marked percentage increases of 25.7, flax; 20.4, cowpeas; 19.3, alfalfa; 15.9, wheat; 4.7, barley; and — 1.1, rye, for the treated over the nontreated soil in the first counts and in the second, 80.9, alfalfa; 51.3, flax; 36.8, cowpeas; 28.2, wheat; 23.0, rye; and 16.3, barley. The first stand count indicated less pre-emergence killing in the treated than in the nontreated soil. The second count showed a greater post-emergence killing in the nontreated soil than in the treated soil.

The percentage germination of the seed planted in the treated soil showed percentage increases of 17.5, flax; 12.4, cowpeas; 12.2, wheat; 10.4, alfalfa; 8.5, barley; and 3.5, rye, over that in the nontreated soil. The increases in the treated soil indicated less pre-emergence and post-emergence killing of the seedlings.

The percentage increases in green weight of the plants grown in the treated soil over the plants grown in the nontreated soil indicated marked increase in size of the plants. The plants grown in the treated soil were larger and more vigorous in appearance than the plants grown in the nontreated soil.

The percentage increases in dry weight indicated that not only did the plants grown in the treated soil have a healthier, more vigorous appearance but that the plants actually had more substance to them.

The grain yields showed increases of 358.3, 120.4, and 60.9 per cent for the barley, wheat, and flax, respectively.

The results obtained from the second planting at Conesville appear in Table 2. Seedling stand counts showed even more marked increases for the treated over the nontreated soil although the stands were numerically smaller. Because of an extended dry period that followed the second planting, the initial seedling stand counts could not be taken for four weeks. The second counts showed percentage increases of 122.8, alfalfa; 102.0, flax; 71.4, barley; 39.0, rye; 29.6, cowpeas; and 24.8, wheat, in favor of the treated plots.

The percentage germination of the seed was not so great in the second planting as in the first because of the delay in germination caused by the dry weather. The percentage increases of germination for the treated over the nontreated soil, however, were greater. The percentage increases were 18.8, barley; 17.2, rye; 10.5, cowpeas; 11.9, alfalfa; 10.5, wheat; and 8.8, flax.

Similarly, the percentage increases of green weight, dry weight, and yield were greater for the treated than for the nontreated soil. The increases were larger in the second planting than in the first. It is especially noticeable that the increases for alfalfa were much greater than in the first planting.

The results obtained from the early planting at Kanawha appear in Table 3. As in the first planting at Conesville, marked increases occurred in seedling stand, germination, green weight, dry weight, and yield for the treated over the nontreated soil. The differences, however, were not so

great. The crops responded much the same at Kanawha as in the Conesville planting although the response of wheat was not so evident. The response of the sugar beets was very pronounced. The increase in green weight of 349.8 per cent and in dry weight of 606.7 per cent refer to only the sugar beet roots.

TABLE 1

CHLORPICRIN TREATMENT OF FIELD SOIL IN RELATION TO STAND AND YIELD OF CROP PLANTS AT CONESVILLE. PLANTED APRIL 9, 1941

CROP	PERCENTAGE GERMINATION		PERCENTAGE INCREASE OF TREATED OVER NOT TREATED				
			Seedling Stand		Green Weight	Dry Weight	Yield
	Treated	Not Treated	4-25-41	5-9-41			
Wheat.....	88.5	76.3	15.9	28.2	75.0	136.4	120.4
Barley.....	90.5	82.0	4.7	16.3	188.9	266.7	358.3
Flax.....	85.5	68.0	25.7	51.3	11.4	57.8	60.9
Rye.....	65.0	61.5	-1.1	23.0	.....	.....	.....
Alfalfa.....	64.2	53.8	19.3	80.9	13.0	47.4	.....
Cowpeas.....	73.6	61.2	20.4	36.8	-8.9	-11.1	.....

TABLE 2

CHLORPICRIN TREATMENT OF FIELD SOIL IN RELATION TO STAND AND YIELD OF CROP PLANTS AT CONESVILLE. PLANTED APRIL 26, 1941

CROP	PERCENTAGE GERMINATION		PERCENTAGE INCREASE OF TREATED OVER NOT TREATED				
			Seedling Stand		Green Weight	Dry Weight	Yield
	Treated	Not Treated	5-23-41	6-5-41			
Wheat.....	71.0	54.5	30.3	24.8	126.1	185.7	147.6
Barley.....	60.5	41.7	45.2	71.4	328.6	471.2	450.0
Flax.....	20.5	11.7	74.8	102.0	-5.8	28.6	91.3
Rye.....	50.0	32.8	52.3	39.0	.....	.....	.....
Alfalfa.....	21.1	9.2	128.2	122.8	116.7	233.3	.....
Cowpeas.....	52.8	42.3	24.8	29.6	5.7	30.0	.....

The percentage germination of seeds in both the treated and non-treated soil was lower than that of the first planting at Conesville. The soil at Kanawha was much colder than at Conesville, and freezing temperatures occurred at Kanawha after the first planting.

The percentage increases in seedling stands, germination, green weight, dry weight, and yield were more pronounced in the second planting at Kanawha than in the first, as is evident from a comparison of Tables 3 and 4. This planting was also followed by a dry period, which delayed germination and gave numerically smaller stands although greater percentage increases.

Isolations were made from diseased tissues of each crop grown at each location. *Pythium debaryanum*, *P. graminicola*, and other fungi were obtained from plants grown in the treated and in the nontreated areas but were isolated more frequently from plants grown in the nontreated soil.

At each location the percentage increase of seedling stand of the second plantings was generally higher than the percentage increase of the earlier plantings although the actual stands were numerically smaller. The data indicated that the seed planted in the treated soil was afforded protection of some type because of the increased number of seedlings in the treated soil. Since the soil was treated with a fungicide and since the seedlings that were examined showed less damage to the root by pathogens when grown in the treated soil, it is probable that there was a smaller population of soil-borne pathogens in the treated soil than in the nontreated soil.

The difference in percentage germination of seeds of the first and second plantings probably can be attributed to rain that fell shortly after the first plantings in sufficient quantity to insure germination and the period of dry weather that followed the second plantings.

Increases of green weight, dry weight, and yield for the second plantings over those of the first plantings perhaps are attributable to several factors. The stands of the second plantings were thinner, thus causing less intra-row plant competition for food, minerals, and water. The soil was warmer and thus was more favorable for the growth of plant pathogens such as *Pythium debaryanum* and *P. graminicola*. The plants of the second plantings growing in the nontreated soil probably were more severely attacked by pathogens than the plants of the first plantings. Examination of the root systems of the seedlings gave some basis for this assumption. Thus, although the plants of the second plantings growing on treated soil were not better than the plants of the first plantings growing on treated soil, the plants of the second plantings growing on nontreated soil were strikingly poorer than the plants of the first plantings growing on nontreated soil. The actual percentage increases of green weight, dry weight, and yield for plants in the treated soil over those in the nontreated soil were greater in the second plantings than in the first plantings because of greater differences between the plants growing on treated soil and plants growing on nontreated soil within the same planting.

The plants growing at Conesville and at Kanawha showed in every case a more vigorous top growth on the plants in the treated soil than on those in the nontreated soil. The roots of the plants growing in the treated soil were also more extensively developed and freer of disease symptoms.

The sugar beet plants in the Kanawha plot responded more strikingly to the decreased pathogen population of the treated soil than any of the other crops. Sugar beets growing on the treated soil showed top growth 3 to 10 times greater than the beets growing in the nontreated soil. The roots were larger, heavier, and more symmetrical in shape. The barley plants at both stations also exhibited marked improvement over the plants

TABLE 3

CHLORPICRIN TREATMENT OF FIELD SOIL IN RELATION TO STAND AND YIELD OF CROP PLANTS AT KANAWHA. PLANTED APRIL 16, 1941

CROP	PERCENTAGE GERMINATION		PERCENTAGE INCREASE OF TREATED OVER NOT TREATED				
			Seedling Stand		Green Weight	Dry Weight	Yield
	Treated	Not Treated	5-1-41	5-16-41			
Oats.....	81.7	70.5	15.8	5.7	52.4	44.4	8.2
Barley.....	43.5	40.8	6.5	18.7	84.1	94.2	131.3
Wheat.....	47.2	36.2	30.4	4.2	20.0	39.4	37.9
Flax.....	32.3	24.7	30.6	16.8	37.5	84.4	48.2
Sugar beets...	23.7	16.4	56.4	44.7	349.8	606.7	.....
Alfalfa.....	18.9	19.8	-4.7	-10.8	0.0	0.0	.....

TABLE 4

CHLORPICRIN TREATMENT OF FIELD SOIL IN RELATION TO STAND AND YIELD OF CROP PLANTS AT KANAWHA. PLANTED MAY 2, 1941

CROP	PERCENTAGE GERMINATION		PERCENTAGE INCREASE OF TREATED OVER NOT TREATED				
			Seedling Stand		Green Weight	Dry Weight	Yield
	Treated	Not Treated	5-17-41	5-29-41			
Oats.....	77.2	75.7	-3.3	2.2	79.6	68.4	43.9
Barley.....	71.0	57.8	2.0	30.7	220.0	180.0	201.2
Wheat.....	53.7	37.5	43.1	56.1	133.3	133.3	79.6
Flax.....	88.3	75.1	17.6	32.9	23.8	39.1	10.8
Sugar beets...	50.8	43.9	15.6	23.1	264.7	415.3	.....
Alfalfa.....	44.8	22.5	54.0	63.7	50.0	65.0	.....

growing in the nontreated soil. The leaf, stem, and fruit development was much better on the plants growing in the treated soil than on the plants growing in the nontreated soil.

Because of some unknown and apparently uncontrolled factors, the rye seed germinated irregularly. The rye seedlings were severely attacked by stem rust so that green weight, dry weight, and yield data could not be obtained. The cowpeas were so severely injured by frost that the data obtained from them were not considered to be valid. In the second planting at Conesville the green weight of the flax showed a negative value. This cannot be explained by either the data or observations. Similarly, the alfalfa and oat seedling count data were contradictory in the first and second plantings at Kanawha.

## SUMMARY

Plots of two types of field soil were treated with chlorpicrin in the fall of 1940 and planted to oats, barley, wheat, rye, flax, cowpeas, alfalfa, and sugar beets in the spring of 1941. Data were obtained showing the

effect on the germination, growth, and development of the crops throughout the season.

Seedling stand counts were from 0 to 128.2 per cent greater for plantings made on the treated soil than for plantings on adjacent nontreated soil.

Isolations from diseased root tissue of seedlings grown in the treated soil yielded fewer isolates of *Pythium debaryanum*, *P. graminicola*, and other fungi than did isolations from seedlings grown in the nontreated soil.

Plants growing in the treated soil were more vigorous, taller, larger stemmed, larger leaved, and darker green in color than plants growing in the nontreated soil. These differences were so marked as to be readily apparent to the casual observer.

All plants growing in the treated soil showed benefits from the soil treatment in their course of development. The sugar beets showed 606.0 per cent increase in dry weight, and the barley showed 450.0 per cent increase in yield.

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# MORPHOLOGY OF THE DIGESTIVE TRACT OF *CYNAEUS* *ANGUSTUS* Le C., A TENEBRIONID.

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The stored-corn beetle, *Cynaesus angustus* Le Conte, has been under observation as an economic pest in federal granaries of stored-corn in Iowa. Its significance in this regard and its life history constitute another study, soon to be published by Jack L. Krall. The present study of this tenebrionid beetle was undertaken jointly in connection with comparative histology studies by David T. Jones. The authors are under obligation to the staff members of the Department of Zoology and Entomology of Iowa State College for facilities and encouragement, particularly to Dr. C. J. Drake and Dr. C. H. Richardson.

Approximately a dozen dissections were made by the two authors as a basis for Figure 1. These dissections, made with fine-pointed Bohemian insect pins under a solution of 10 per cent formalin, were pinned out for study in paraffined-bottomed Stender dishes in either 5 per cent formalin or 70 per cent alcohol. Observations were made under the binocular microscope, under strong illumination. Since the average size of the beetles prior to dissection ranged between 4.57 and 6.09 mm., the dissections of the digestive tract required not only extreme care and patience but no small amount of acquired skill.

The standard paraffin method was used in histological work, though modifications for delicate objects were introduced: specifically, cold xylene mush or cold chloroform mush in infiltrating to shorten to a minimum the exposure of the tissues to heat. Fixatives used were Carnoy's fluid, Bouin's fluid, and 10 per cent formalin. With Carnoy's fluid the fixation time varied from 15 to 20 minutes according to the size of the tissue. With Bouin's fluid or 10 per cent formalin, the fixation time was increased to 1 hour. Sections were cut at 8 micra and stained with Ehrlich's acid hematoxylin and eosin, or with Heidenhain's iron hematoxylin.

The mandibles of *Cynaesus angustus* are relatively simple. Between these lie the mouth, which opens into a more-or-less distinct pharynx which varies from a bulbous shape when distended to a flaccid sac, the limits of which are barely discernible as it tapers into the tubular oesophagus. The slender oesophagus dilates posteriorly into a pinkish proventriculus. Following this is the ventriculus, covered with numerous regenerative crypts, which organ comprises the greater part of the digestive tract. A study of the larger tenebrionid, *Nyctobates pennsylvanica* De Geer, which in the vicinity of Ames lives under the bark of trees and fallen logs, discloses that the long ventriculus studded with



many regenerative crypts is characteristic of the tenebrionid group. This is also confirmed by the literature. At the posterior end of the ventriculus, delicate unbranched Malpighian tubules join the digestive tract. These we find to be apparently six in number, though their fragility as they are mingled with the regenerative crypts and slender tracheoles render identification of the broken stubs very difficult. The literature (Snodgrass) is indefinite as to whether tenebrionids have four or six Malpighian tubules. The intestine which follows the ventriculus is quite variable. In some specimens it seems to have, in its natural position, a rather constant and relatively simpler looping than that shown in Figure 1. Its anterior and posterior dilations might well signify, respectively, anterior and posterior intestine, but if so, the intermediate region, usually containing faecal pellets, would have to be arbitrarily assigned to one or the other portions as it contains no natural division. The rectum, however, is quite distinct. This study does not attempt to describe the anatomical relation of the posterior rectum to the organs of reproduction in the two sexes.

Histologically the stomodaeal derivatives (pharynx, oesophagus, and proventriculus) are lined with chitinous intima, consisting for the most part of prominent yellow spicules, which are variable in different regions, not only as to length, but as to grouping. Beneath these is a wide elastic membrane which is constricted in fixed preparations. Adipose masses lie in close proximity to the stomodaeal portions of the digestive tube. In the pharyngeal region these appear in some specimens very much like salivary glands (see Fig. 2), though glandular structure is not evident.

Histological sections show the regenerative crypts of the ventriculus pinched off from the lumen by an overgrowth of the epithelium lining the lumen. These (Fig. 5) are proportionately longer and less vacuolated in *Cynaesus angustus* than those of the larger tenebrionid, *Nyctobates pennsylvanica* (Fig. 7). Both species show gregarine infestation of the ventriculus, though the fragments in the two beetles appear different. Figure 5 is a composite drawing from several slides. Figure 7, on the other hand, is from only one section, except for the gregarines. In this figure the one labelled "g" is shown as it appeared with long protomerite. Others are from other sections and slides of other specimens. The one with the blunt protomerite (next to the Fig. 7) appears to be *Asterophora philica* (Leidy) (Kudo, pp. 297-98). The striated musculature in the ventriculus of *Cynaesus angustus*, if present, is certainly very inconspicuous as compared with that in the ventriculus of *Nyctobates pennsylvanica*. The histology of the Malpighian tubules and intestinal region is relatively simple (Fig. 6). The specimens examined showed no fungal infestation of the epithelium of the Malpighian tubules as found in the cluster fly (Jones).

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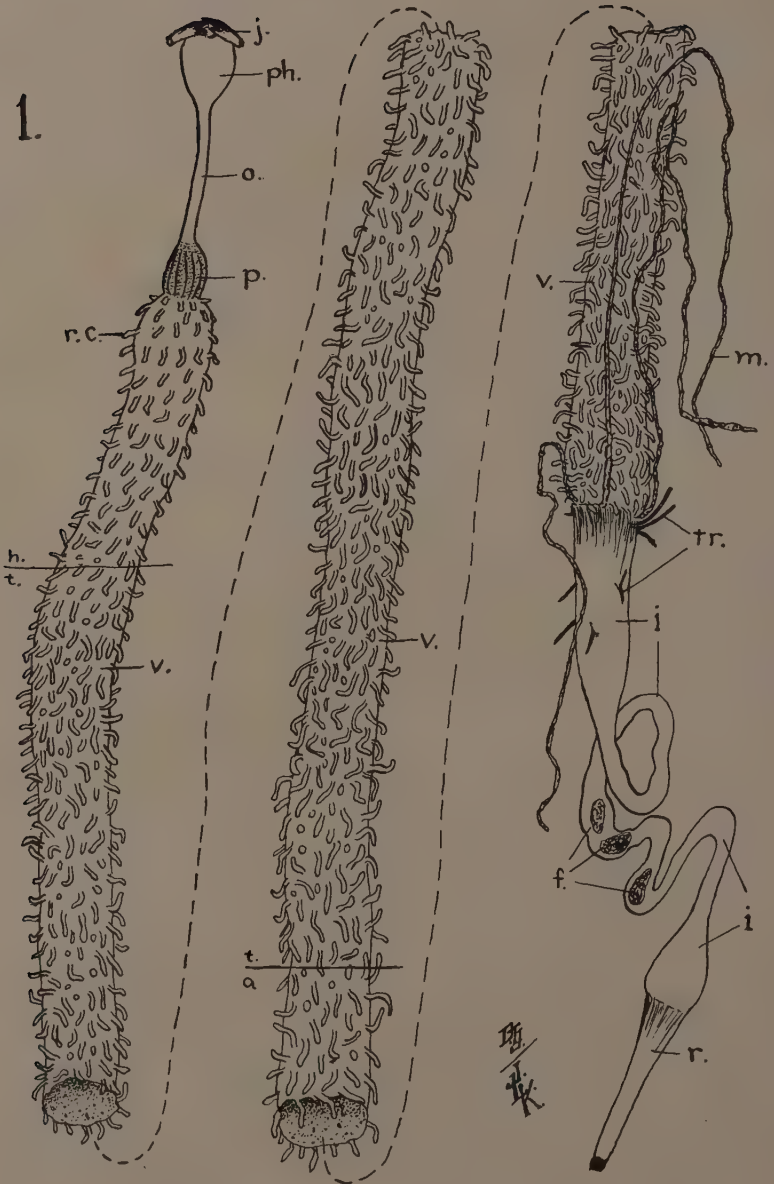
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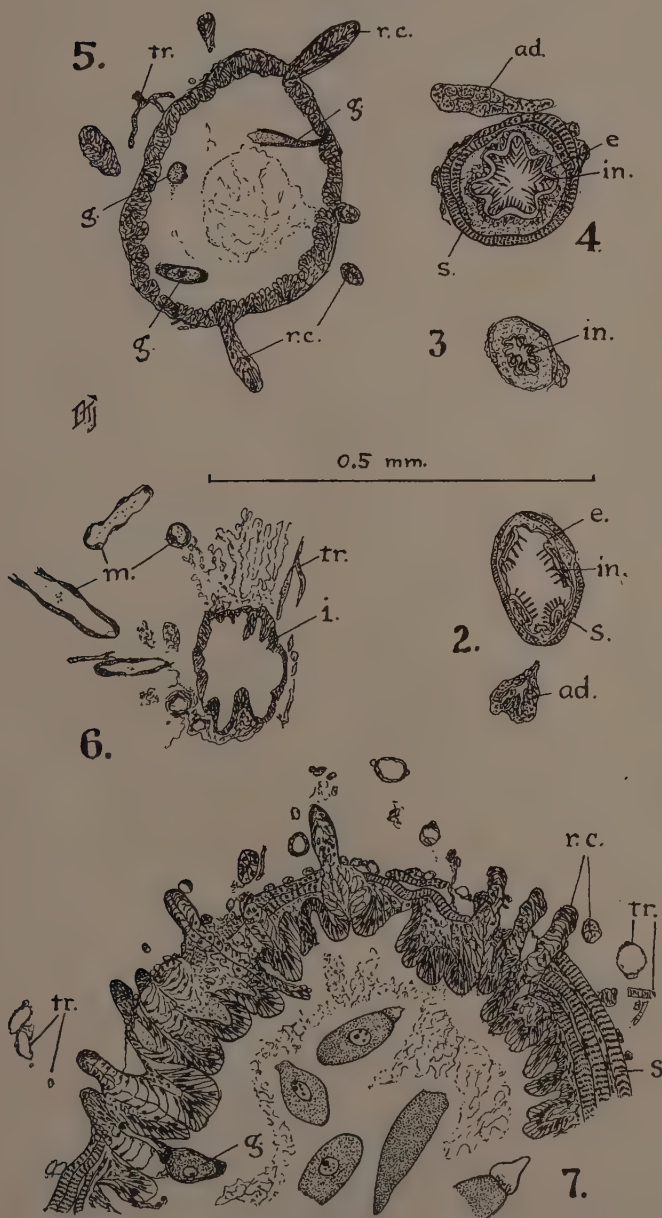
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#### KEY TO FIGURES

1. Anatomy of the digestive system of *Cynaesus angustus*.
  2. Cross section of the pharynx of *Cynaesus angustus*.
  3. Cross section of oesophagus of *Cynaesus angustus*.
  4. Cross section of proventriculus of *Cynaesus angustus*.
  5. Cross section of ventriculus of *Cynaesus angustus*.
  6. Cross section of intestine of *Cynaesus angustus*.
  7. Cross section of portion of ventriculus of *Nyctobates pennsylvanica*.
    - a. Position of anterior abdomen with reference to thorax.
  - ad. Adipose tissue.
  - e. Elastic membrane.
  - f. Faecal pellet.
  - g. Gregarine parasite.
  - h. Position of head relative to thorax.
  - i. Intestine.
  - in. Intima.
  - j. Jaws.
  - m. Malpighian tubule.
  - p. Proventriculus.
  - r. Rectum.
  - r.c. Regenerative crypt.
  - s. Striated muscle.
  - t. Position of the thorax relative to head or to abdomen.
  - tr. Tracheole.
  - v. Ventriculus.
- Scale applies to figs. 2-7.







## STUDIES ON THE MYXOBACTERIA

### 3. The Utilization of Carbohydrates<sup>1</sup>

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The type of substrate upon which many of the myxobacteria have been found in nature would seem to indicate the advisability of studying the role that complex carbohydrates may play in the nutrition of these bacteria. The first species to be described, *Polyangium vitellinum* Link 1809, was found growing on an old wicker basket; Thaxter (1892) first observed *Synangium sessile* on decayed wood and *Podangium lichenicolum* on lichens, and later (1904) *Chondromyces catenulatus* on dead poplar wood. *Chondromyces crocatus* Berkeley and Curtis (1857) was noted on melon rind and straw. Most species are able to develop on dung, a substrate that would seem to be high in undigested long-chain carbohydrates such as cellulose. The marked morphological similarities of the cytophagae and myxobacteria as demonstrated by Stanier (1940) make it appear that the two groups may well be united. Physiologically, too, they seem to be alike in certain characteristics. The decomposition of cellulose by members of the genus *Cytophaga* is well known; reports by Mishustin (1938) and others would indicate that certain myxobacteria are to some extent equally capable.

In 1930 Mme Krzemieniewski found cellophane (cellulase acetate) to be a suitable carbon source for *Spirochaeta cytophaga*. Johnson (1932) reported the breakdown of the chitinous exoskeleton of the hard-shelled crab by species of both *Cytophaga* and *Myxococcus*, and Benton (1935) isolated a number of chitin-dissolving bacteria, several of which appeared to be myxobacteria. Stanier (1940) found that agar and cellulose were decomposed by certain species of *Cytophaga*, but that starch and chitin were not attacked. Krzemieniewski (1937) and Imsenecki and Solntzeva (1937) reported at least partial decomposition of cellulose by several species of myxobacteria.

The present investigation has to do with the abilities of several species of the Myxobacteriales to utilize various carbon compounds.

#### EXPERIMENTAL PROCEDURES AND RESULTS

The first experiments were run in order to compare the growth of species of *Myxococcus*, *Chondrococcus*, *Podangium*, and *Polyangium* on cellulose and on cellobiose, dextrose, sucrose, and lactose. A mineral salt medium of the following composition was used:

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$K_2HPO_4$ .....	2.50 gm.
$MgSO_4$ .....	1.25 gm.
$NaCl$ .....	1.25 gm.
$KNO_3$ .....	9.00 gm.
$MnSO_4$ .....	Trace
$FeSO_4$ .....	Trace
Distilled $H_2O$ .....	1.00 liter

One part of the above solution was diluted with four parts of distilled water. One per cent calcium carbonate, 1.5 per cent Bacto agar, and 0.5 per cent of the carbohydrate were added. In the study of cellulose a piece of sterile filter paper was floated on the agar before the latter had solidified. The indicator was brom-cresol-purple. Sterilization was effected in the autoclave at 15 pounds steam pressure for 20 minutes. Plates were inoculated by transferring a fruiting body, by means of a needle, from the stock culture to the center of the plate. Incubation was at 30°C. for 7 days. At the end of that time the diameters of the colonies were recorded in millimeters.

None of the carbohydrates was broken down to give an acid reaction. Subsequent work has shown that few, if any, of the species that have been studied will survive in a medium whose pH is much below 6.5. In general, development on filter paper was best; no apparent preference was shown for any of the other carbon compounds employed.

The experiment was repeated without calcium carbonate in the medium. Growth was about the same: very poor compared to that on suspensions of bacterial cells (a point brought out in a previous article), but still recognizable as growth. In the first experiment it had been found that the filter paper used as a source of cellulose had a rather high starch content, as shown by testing with iodine. In the second trial, a paper was substituted which gave a negative iodine test, and starch, as a carbon source, was added to the list of compounds already mentioned. Very little difference in growth was noted on any of the media. That on starch agar was as rapid as that on any of the other substrates, but fruiting bodies were formed in only a few instances. The starch in the area of growth, and often in a much larger area, was broken down. The starch agar medium outside of the growth area gave a positive test for starch with dilute iodine; that within was definitely negative. Amylase production seemed probable. In no case was growth as rapid as had been expected.

In reviewing the data, it was thought that the concentrations of the carbohydrates might be too low to be significant. A somewhat modified mineral salt-agar medium was employed in the following work. It was made up as follows:

$K_2HPO_4$ .....	2.00 gm.
$MgSO_4$ .....	0.50 gm.
$NaCl$ .....	0.20 gm.
$CaCl_2$ .....	0.20 gm.

MnSO <sub>4</sub> .....	Trace
FeSO <sub>4</sub> .....	Trace
Distilled H <sub>2</sub> O .....	1.00 liter

One and one-half per cent agar was added, and for the first trial no additional nitrogen or carbon sources were included. The plates were incubated at room temperature (22°–25°C.) for 7 days. The results are shown in Table 1.

TABLE 1  
GROWTH ON MINERAL SALT-AGAR  
7 Days—Room Temperature

Name of Organism	Diameter of Colonies in Millimeters
<i>Myxococcus fulvus</i> 44.....	8.4
<i>Polyangium fuscum</i> 77.....	6.5
<i>Podangium erectum</i> 82.....	13.0
<i>Myxococcus virescens</i> 91.....	4.5
<i>Chondrococcus blasticus</i> 111.....	11.5
<i>Myxococcus xanthus</i> 127.....	9.0

Controls used in connection with work on the parasitism of the myxobacteria had indicated that growth might be possible on agar alone. Here the addition of the inorganic salt solution to the agar appeared to be sufficient to support moderately good development. Often no better growth had been recorded on dung decoction agar under similar conditions. Omission of a source of nitrogen suggested that that element as well as carbon was furnished by the agar. Various carbon and nitrogen sources were then combined.

A representative series of carbohydrates starting with a five-carbon sugar, arabinose, and ending with cellulose, was employed. Cellulose was reprecipitated by dissolving 10 grams of absorbent cotton in 100 cc. of concentrated H<sub>2</sub>SO<sub>4</sub> diluted with 60 cc. of distilled water. About 1 minute was required to dissolve the cotton. When it was completely in solution, 2 liters of water were quickly added, and shaken well. The cellulose precipitated out and was removed by filtration. The precipitate was washed repeatedly until the filtrate gave a negative test for sulfates with barium chloride. The cellulose was resuspended in 100 cc. of distilled water. This was considered as a 10.0 per cent suspension, and was diluted as needed.

Other carbohydrates employed were mannose, maltose, sucrose, glycerol, dulcitol, inulin, and starch, all, including arabinose and cellulose, in concentrations of 1.0 per cent. In their work on several species of *Cytophaga*, Stapp and Bortels (1934) found nitrogen could best be supplied by the simpler inorganic compounds, amino acids failing to be of particular value. Stanier (1940) also noted that species of the same group could not utilize amino nitrogen; however, he reported peptone and yeast extract to be the only suitable nitrogen sources. In connection with the present work, ammonium sulfate and sodium nitrate were the first nitrogen

sources to be tried. Including the system of controls, thirty different combinations of inorganic nitrogen salts and carbohydrates were prepared.

The same six species of myxobacteria were employed in this experiment. Incubation was at room temperature for a period of 6 days. The colonies were measured at the end of each 3 days in order to get some idea of the rates of growth. The main object of the experiment, however, was to compare the values of the various carbon and nitrogen sources. Results for the 6-day period are presented in Table 2.

TABLE 2  
GROWTH ON COMBINATIONS OF VARIOUS CARBON AND NITROGEN SOURCES  
Diameters of Colonies in mm.  
6 Days—Room Temperature

Culture and Number	Carbohydrates—1.0 per Cent									
	Control	Arabinose	Mannose	Maltose	Sucrose	Glycerol	Dulcitol	Inulin	Cellulose	Starch
	Control—No Added Source of N.									
<i>M. fulvus</i> 44....	6.0	1.5	3.5	3.5	4.5	7.5	7.0	6.0	7.0	10.0
<i>P. fuscum</i> 77....	6.0	1.0	1.5	1.0	7.0	4.7	6.0	9.0	9.5	13.0
<i>P. erectum</i> 82....	11.0	0.6	5.0	3.5	5.0	9.0	14.0	13.0	10.0	10.0
<i>M. virescens</i> 91..	3.0	0.5	2.0	1.0	3.5	3.7	4.2	4.0	3.5	6.0
<i>C. blasticus</i> 111..	5.0	1.1	2.3	3.5	5.5	4.0	4.5	4.0	7.0	8.0
<i>M. xanthus</i> 127..	9.0*	2.0	5.5	6.7	11.0	10.0	8.5	9.5	8.0	7.5
	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> —2.5 Grams per Liter									
<i>M. fulvus</i> 44....	3.5	2.0	2.0	4.0	6.5	8.0	9.0	9.7	5.0	8.5
<i>P. fuscum</i> 77....	3.0	1.0	1.0	3.0	2.7	5.0	1.5	7.0	6.5	11.0
<i>P. erectum</i> 82....	9.0	1.0	9.0	3.5	6.5	4.0	19.0	17.0	9.0	13.0
<i>M. virescens</i> 91..	2.5	1.5	3.0	3.0	3.5	3.5	3.0	5.5	3.0	9.0
<i>C. blasticus</i> 111..	2.0	1.0	.....	5.0	7.0	3.7	7.5	9.0	4.7	9.0
<i>M. xanthus</i> 127..	4.7	3.2	5.5	7.0	8.5	6.5	8.0	12.0	7.5	13.0
	NaNO <sub>3</sub> —2.5 Grams per Liter									
<i>M. fulvus</i> 44....	6.0	1.3	2.0	1.2	6.0	4.5	6.0	4.5	4.0	8.0
<i>P. fuscum</i> 77....	2.3	1.0	0.7	1.0	1.5	2.0	4.0	1.0	1.0	6.0
<i>P. erectum</i> 82....	4.5	1.5	0.5	1.0	5.0	1.0	4.5	5.0	1.2	6.0
<i>M. virescens</i> 91...	5.0	2.0	2.5	1.5	6.0	4.5	4.0	5.0	3.0	7.0
<i>C. blasticus</i> 111..	5.2	2.3	3.0	1.8	4.7	2.5	4.5	4.0	5.0	5.0
<i>M. xanthus</i> 127..	9.5	1.5	4.0	3.0	9.0	8.5	7.5	8.5	6.0	10.0

\*Figures in boldface indicate formation of fruiting bodies.

In contrast to those media containing only 0.5 per cent carbohydrate, the results here show a very definite trend:

1. In concentration of 1.0 per cent, arabinose completely inhibits the growth of the species under examination. On this sugar, in combination with ammonium sulfate, *M. xanthus* 127 appears to have developed somewhat; actually the diameter of the colony increased only 0.2 mm. in

3 days, the reading for the third day being 3.0 mm. Complete inhibition of the growth of all other species is obvious.

2. Mannose and maltose usually, but not always, prevented growth. In combination with ammonium sulfate, and without a nitrogen source, *Podangium erectum* developed moderately well on mannose, poorly on maltose. *M. xanthus* showed only very modest growth on both sugars.

3. The first sugar in the series that permitted more or less normal development of all species was sucrose. It appeared to have little effect, neither inhibiting growth seriously nor stimulating it noticeably. Results were comparable to those on the control. Effects of the source of nitrogen were not significant.

4. Glycerol showed a slight inhibitory effect in some instances, though never so marked as that produced by arabinose, mannose, and maltose. In a few cases it appeared to stimulate development to some degree.

5. For the most part dulcitol and inulin favored growth. Stimulation was especially marked in the case of *P. erectum* on the nitrogen control, and with ammonium sulfate added. All other species produced moderate to very good growth on these carbohydrates.

6. Best growth was had on reprecipitated cellulose and on starch, the latter usually being the better. *Myxococcus virescens*, normally a slow-growing species, developed rapidly on all of the starch media; on cellulose the growth of this organism was not much better, if any, than on the carbohydrate controls.

7. There appeared to be no significant difference between growth on the nitrogen controls and on those media to which inorganic nitrogen had been added. In several cases growth on the control exceeded that on the other two media.

8. Fruiting body formation was below normal throughout, being almost as poor on starch and cellulose as on arabinose.

In an additional series of tests, nitrogen was supplied as ammonium phosphate and potassium nitrate, the carbon sources remaining the same. The results of this second run are essentially the same as those of the previous experiment. They are shown in Table 3.

Again it may be noted that the various inorganic sources of nitrogen failed to have any effect on the growth of the species under consideration. Growth on the five- and six-carbon sugars was wholly or partially inhibited in every case, while increasing the size of the carbohydrate molecule was followed by a direct increase in the rate of growth of all species. Starch and reprecipitated cellulose appeared to have the most marked stimulative effects, but did not promote the formation of fruiting bodies to any great extent. Within the area of growth the starch agar failed to give a positive iodine test for starch.

It was previously noted that media containing 0.5 per cent of certain carbohydrates seemed to have but little effect on the growth of some species of myxobacteria. To better compare the effects of varying the concentrations, agar media containing both 0.5 per cent and 2.0 per cent of

carbohydrates were prepared. Nitrogen sources were omitted, since they appeared to have no effect. The same species of myxobacteria were employed. The results, for a 6-day incubation period at room temperature, may be seen in Table 4.

TABLE 3  
GROWTH ON COMBINATIONS OF VARIOUS CARBON AND NITROGEN SOURCES  
Diameters of Colonies in mm.  
6 Days—Room Temperature

Culture and Number	Carbohydrates—1.0 per Cent									
	Control	Arabinose	Mannose	Maltose	Sucrose	Glycerol	Dulcitol	Inulin	Cellulose	Starch
(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub> —2.5 Grams per Liter										
<i>M. fulvus</i> 44....	6.0	1.5	2.0	2.0	6.5	6.0	7.0	7.0	9.5	7.0
<i>P. fuscum</i> 77....	7.0	1.2	1.0	1.5	5.0	3.0	6.0	12.0	1.0	1.0
<i>P. erectum</i> 82....	3.5	1.0	1.0	1.0	2.0	1.0	3.0	12.0	19.0	.....
<i>M. virescens</i> 91....	4.0	1.5	1.5	1.3	3.0	2.0	2.5	4.0	5.0	.....
<i>C. blasticus</i> 111....	5.0	1.7	1.0	1.0	3.0	3.5	3.0	7.0	8.0	.....
<i>M. xanthus</i> 127....	7.5	1.5	3.0	1.0	9.0	7.0	6.5	9.0	10.5	.....
KNO <sub>3</sub> —2.5 Grams per Liter										
<i>M. fulvus</i> 44....	10.5	1.0	4.0	5.0	8.5	6.0	9.0	.....	8.0	19.0
<i>P. fuscum</i> 77....	5.0	1.1	0.8	1.5	4.0	2.0	3.0	5.5	4.5	7.0
<i>P. erectum</i> 82....	15.0	1.2	7.5	1.7	7.0	2.5	14.0	10.0	20.0	19.0
<i>M. virescens</i> 91....	8.0	0.8	2.0	2.5	6.5	6.5	5.0	8.0	5.0	10.0
<i>C. blasticus</i> 111....	10.0	1.3	4.5	4.5	8.5	1.5	9.0	15.0	8.0	25.0
<i>M. xanthus</i> 127....	14.0	1.2	7.0	7.5	14.0	10.5	11.0	12.5	10.0	20.0

It will be noted that inhibition increased directly with the concentration of the pentoses and hexoses, growth in every case being greater on the 0.5 per cent concentrations than on the 2.0 per cent. Sucrose and dulcitol partially inhibited growth in the higher concentrations, but appeared to have a slight stimulative effect in the lower, while inulin and reprecipitated cellulose generally favored growth of all species irrespective of concentration.

The average results with starch were about the same with both concentrations, appearing to serve as the best carbon source. The starch was invariably broken down.

Gum arabic, a compound that might conceivably be utilized as a natural carbohydrate substrate, was substituted for glycerol. In general it appeared to be less desirable as a source of carbon than starch, showing in several instances, a slight inhibitory effect in the higher concentrations.

No fruiting bodies were produced by any species on either the 0.5 per cent or the 2.0 per cent concentrations of arabinose, while on mannose and maltose fruiting body production was limited to the lower concentrations of these sugars. The compounds in this series above maltose had little effect on fruiting body formation, irrespective of concentration. *Podan-*

TABLE 4  
COMPARISON OF GROWTH ON TWO CONCENTRATIONS OF CARBOHYDRATES  
Diameters of Colonies in mm.  
6 Days—Room Temperature

Culture and Number	Percentage Carbohydrate	Control	Arabinose	Mannose	Maltose	Sucrose	Dulcitol	Inulin	Cellulose	Starch	Gum arabic
<i>M. fulvus</i> 44.....	0.5 2.0	11.0 8.0	5.5 1.5	5.0 3.0	4.7 4.0	6.0 4.5	5.0 7.0	5.0 9.5	8.0 5.5	11.0 14.0	10.0 7.0
<i>P. fuscum</i> 77.....	0.5 2.0	9.0 13.5	3.0 1.0	6.5 1.0	7.0 2.0	12.0 13.0	8.0 2.5	15.0 9.0	23.0 23.0	18.0 28.0	15.0 32.0
<i>P. erectum</i> 82.....	0.5 2.0	25.0 20.0	2.0 1.0	18.0 2.0	6.0 1.5	5.0 7.5	25.0 10.0	20.0 28.0	15.0 7.0	20.0 15.0	22.0 12.0
<i>M. virescens</i> 91.....	0.5 2.0	7.5 3.5	2.0 1.0	2.7 2.0	4.0 1.0	5.7 2.5	5.5 3.5	6.0 4.0	6.0 4.0	9.0 7.0	8.0 7.0
<i>C. blasticus</i> 111.....	0.5 2.0	12.0 8.5	3.0 1.0	7.0 1.5	8.0 4.2	11.0 5.0	9.0 6.0	10.5 7.0	10.0 8.0	15.0 17.0	10.0 .....
<i>M. xanthus</i> 127.....	0.5 2.0	11.0 14.0	7.0 1.0	8.0 3.5	12.0 8.0	15.0 12.0	11.0 10.5	14.0 14.0	10.0 8.5	17.5 16.0	16.0 10.0



*gium erectum* and *Myxococcus xanthus* were the only species to mature, i.e., produce fruiting bodies, on the majority of these media; fruiting bodies of *Polyangium fuscum* were seen only on the lower concentrations of starch and gum arabic.

In their natural environment, soil and dung, the Myxobacteriales might be expected to utilize a substrate composed of both bacterial cells and carbohydrates of one kind or another. Chief among the latter probably would be cellulose, as such or partially broken down by the action of the myxobacteria themselves, or by other cellulose-decomposing organisms. It is not impossible that other somewhat less complex carbohydrates might be present. To determine the comparative effects of associated bacterial cells and carbohydrates, several media were devised containing varying amounts of both dried bacterial cells and starch; starch because it seemed the most readily utilized of all those polysaccharides that had been examined. The cells used for the suspensions were *Escherichia coli*. It was pointed out in an earlier article that a substrate containing gram-negative cells might be slightly more favorable than one containing gram-positive cells. The media were prepared with 00.0, 10.0, 25.0, and 50.0 mgm. of dried cells per 100.0 cc. of solution, and 0.0, 0.5, 1.0, and 2.0 per cent of starch. No mineral salt or other nutrient solution was added to any of the media. Agar was in 1.5 per cent concentration. Inoculations were made in the usual way.

The results of this test, shown in Table 5, indicate that on the cell control media (those containing no suspended bacterial cells) better growth was had with a small amount of starch, i.e., 0.5 per cent, than with no starch. However, this concentration seemed to be sufficient for the needs of the organisms. Above 0.5 per cent slight increases in rates of growth were noted up to and including 1.0 per cent concentration; above this point there appeared to be no significant changes in the rates of development of most species.

With the addition of 10.0 mgm. of dried, and killed, bacterial cells to the medium a definite increase in the size of the colonies was observed, and additional increases in colony size followed directly, for the most part, increases in the concentrations of cells in the media up to and including 25.0 mgm. per 100.0 cc. Above that point changes in rates of growth were negligible. The most marked increases in rates of development, following additions of dried cells to the media, were to be noted in those containing 0.5 per cent starch, or no starch at all; on the media of higher cell content, additional amounts of starch often caused slight decreases in growth. This is particularly noticeable in cases of those species belonging to the family Myxococcaceae. For example, *M. fulvus* 44 on the medium containing 50 mgm. of cells reached, with no starch present, a diameter of 18.0 mm.; with 0.5 per cent starch its size increased to 34.0 mm.; but with 1.0 per cent and 2.0 per cent starch the colonies were proportionately smaller. *P. fuscum* 77 and *P. erectum* 82 appeared to be less affected by the addition of starch to the substrate.

Fruiting body production followed, more or less directly, the cell

content of the medium. With no bacterial cells in the substrate, only *M. fulvus* 44 and *M. xanthus* 127 formed fruiting bodies. The addition of 10.0 mgm. of cells increased the number of species producing fruiting bodies to three, while all matured on at least one of the media containing

TABLE 5  
GROWTH ON COMBINATIONS OF CELL SUSPENSIONS AND STARCH  
Diameters of Colonies in mm.  
6 Days—Room Temperature

Mgm. of Cells per 100 cc.	Species Name and Number	Percentage Starch			
		0.0	0.5	1.0	2.0
00.0	<i>M. fulvus</i> 44.....	7.0	11.0	8.0	12.0
	<i>P. fuscum</i> 77.....	13.0	22.0	24.5	22.0
	<i>P. erectum</i> 82.....	7.0	8.0	2.0	15.0
	<i>C. blasticus</i> 111.....	5.5	6.0	6.5	5.5
	<i>M. xanthus</i> 127.....	11.5	16.0	11.0	7.0
10.0	<i>M. fulvus</i> 44.....	19.0	16.0	18.0	14.0
	<i>P. fuscum</i> 77.....	20.0	15.0	32.0	44.0
	<i>P. erectum</i> 82.....	47.0	14.0	13.0	12.0
	<i>M. virescens</i> 91.....	7.0	8.0	7.5	6.0
	<i>C. blasticus</i> 111.....	12.0	9.5	24.0	12.0
	<i>M. xanthus</i> 127.....	21.0	20.0	19.0	12.0
25.0	<i>M. fulvus</i> 44.....	22.0	31.0	20.0	20.0
	<i>P. fuscum</i> 77.....	19.0	14.0	15.0	25.0
	<i>P. erectum</i> 82.....	45.0	30.0	14.0	38.0
	<i>M. virescens</i> 91.....	13.0	14.0	12.0	10.0
	<i>C. blasticus</i> 111.....	22.0	29.0	18.0	16.0
	<i>M. xanthus</i> 127.....	23.0	25.0	22.0	19.0
50.00	<i>M. fulvus</i> 44.....	18.0	34.0	20.0	18.0
	<i>P. fuscum</i> 77.....	24.0	14.0	7.0	45.0
	<i>P. erectum</i> 82.....	25.0	28.0	37.0	39.0
	<i>M. virescens</i> 91.....	12.0	16.0	10.0	11.0
	<i>C. blasticus</i> 111.....	22.0	27.0	14.0	18.0
	<i>M. xanthus</i> 127.....	24.0	24.0	18.0	12.0

50.0 mgm. of dried cells per 100.0 cc. As previously noted, increases in starch content of these media were not particularly favorable to fruiting body production.

The effects of the pentoses and hexoses in combination with various suspensions of bacterial cells were approximately as expected. A series of media was prepared using as carbohydrates arabinose, mannose, maltose, sucrose, inulin, and starch in both 0.5 per cent and 1.0 per cent concentrations. For the cell suspensions *Escherichia coli* was employed in concentrations of 00.0, 10.0, and 50.0 mgm. per 100.0 cc. of medium. Inoculation was in the usual manner; incubation was at room temperature for 6 days.

According to the data presented in Table 6, it may be seen that on those media containing 00.0 and 10.0 mgm. of bacterial cells in suspension, arabinose was completely inhibitory in 1.0 per cent concentration, while growth was usually absent or definitely restricted with 0.5 per cent arabinose. On media containing 50.0 mgm. of cells, inhibition by this sugar was not so marked, although development of the colonies was greatly reduced.

On media which contained mannose and maltose in concentrations of 1.0 per cent, colony growth was partially restricted. Although inhibition was less marked with the increase in cell concentrations, it was none the less noticeable.

Sucrose appeared to have very little effect on the growth of any of the species of myxobacteria under consideration, colony diameters on sucrose media comparing favorably with those on the carbohydrate controls. Colony growth is seen to follow directly the changes in concentrations of bacterial cells in suspension in the media.

With no cells in suspension, inulin had a slight inhibitory effect in 1.0 per cent concentrations. With the addition of 10.0 mgm. of dried cells to the medium, growth on the two concentrations of this sugar were approximately equal. The addition of 50.0 mgm. of cells resulted in greater increases in rates of growth with 1.0 per cent inulin than with 0.5 per cent.

In general, 0.5 per cent starch favored development to a higher degree than did 1.0 per cent. This is noticeable in all three cell suspensions, but particularly so in the highest. Growth on a medium containing 50.0 mgm. of dried cells per 100 cc. and 0.5 per cent starch was superior to all others. This was followed by the same concentration of cells with 1.0 per cent starch, and then the 50.0 mgm. cell suspension alone.

The formation of fruiting bodies on the cell control media appears to be limited by the amounts of pentoses and hexoses. In general it may be said that over 0.5 per cent of arabinose, mannose, or maltose is not only inhibitory to vegetative growth but to fruiting body development as well. This effect is not so marked in the highest concentrations of cells, but is very noticeable in those suspensions containing 10.0 mgm. per 100 cc. In combination with heavy cell suspensions, the inhibitory effects of the lowers sugars are not always so great as in the absence of bacterial cells; they may, however, still be noted.

The highest percentage of fruiting bodies was produced on 1.0 per cent sucrose combined with 50.0 mgm. of dried cells; every organism matured. This was followed by 0.5 per cent maltose, 1.0 per cent inulin, and finally starch (both concentrations) and the control.

#### DISCUSSION

The utilization of the carbohydrates by the species of Myxobacteriales that have been under observation appears to be limited to the more complex molecules such as starch and cellulose, inulin, and dulcitol. The pentoses are seen to inhibit growth almost completely, depending upon their concentrations. The presence of more than 1.0 per cent pen-

TABLE 6  
COMPARISON OF GROWTH ON VARYING CELL AND CARBOHYDRATE CONCENTRATIONS  
Diameters of Colonies in mm.  
6 Days—Room Temperature

Mgm. of Cells per 100 cc.	Culture Name and Number	Percentage Carbohydrates												
		Control	Arabinose		Mannose		Maltose		Sucrose		Inulin		Starch	
			0.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5
Control	<i>M. fulvus</i> 44.....	7.0	4.5	1.2	3.5	2.2	6.5	1.0	7.0	7.5	6.0	14.0	12.0	
	<i>P. fuscum</i> 77.....	1.3	0.8	1.0	1.5	1.0	5.0	0.7	8.0	5.0	2.0	1.0	7.0	
	<i>P. erectum</i> 82.....	7.0	3.0	3.0	11.0	2.0	4.0	1.5	7.0	6.0	3.0	15.0	23.0	
	<i>M. virescens</i> 91.....	2.0	1.5	1.5	1.5	1.0	2.5	1.0	2.5	1.5	3.0	1.5	4.0	
	<i>C. blasticus</i> 111.....	6.0	2.5	1.0	4.0	1.0	3.0	2.0	8.0	4.0	5.5	12.0	6.0	
	<i>M. xanthus</i> 127.....	9.0	2.8	1.0	5.0	3.0	7.5	5.0	11.0	10.0	6.5	10.0	10.0	
10.0	<i>M. fulvus</i> 44.....	9.0	7.0	3.5	4.2	5.0	8.0	3.5	9.0	8.5	8.0	18.0	13.0	
	<i>P. fuscum</i> 77.....	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.5	5.5	1.0	3.0	1.0	
	<i>P. erectum</i> 82.....	10.0	2.5	1.5	4.0	0.8	2.0	1.0	4.5	10.0	7.0	5.0	11.0	
	<i>M. virescens</i> 91.....	5.0	1.5	0.7	2.0	1.0	2.0	1.0	5.0	5.5	4.0	7.0	6.0	
	<i>C. blasticus</i> 111.....	9.0	1.5	1.0	2.8	1.5	4.5	3.0	4.0	10.0	5.5	9.0	9.0	
	<i>M. Xanthus</i> 127.....	12.0	1.0	1.2	1.5	3.5	7.8	7.0	13.0	17.0	8.0	15.0	12.0	
50.0	<i>M. fulvus</i> 44.....	15.0	11.0	8.0	7.5	7.0	10.5	5.5	15.0	9.0	15.0	23.0	14.0	
	<i>P. fuscum</i> 77.....	4.5	1.0	1.2	3.5	1.0	1.5	3.0	4.5	10.0	4.5	3.0	4.0	
	<i>P. erectum</i> 82.....	37.0	2.0	1.3	4.5	4.5	11.5	1.0	23.0	19.0	13.0	29.0	23.0	
	<i>M. virescens</i> 91.....	6.5	2.0	1.5	3.0	2.0	3.0	4.0	6.0	6.5	5.0	9.0	1.0	
	<i>C. blasticus</i> 111.....	19.0	6.0	5.0	9.0	6.0	10.0	7.0	15.0	12.0	10.0	21.0	12.0	
	<i>M. xanthus</i> 127.....	18.0	9.0	6.5	9.5	8.0	12.0	13.0	18.0	15.0	15.0	22.0	8.0	

tose usually stops growth, while less than 0.5 per cent will allow restricted development in a few cases. The hexoses seem to be only slightly less inhibitory. Di-saccharides have little, if any, inhibitory action on the growth of these bacteria, but neither do they stimulate development, permitting growth approximate to that on a medium containing no source of carbon other than agar. Beyond this point, and up to and including starch, growth rates seem to increase directly with increases in the length of the carbon chain, when the carbohydrate is in concentration of 1.0 per cent or less. Higher concentrations of even the largest carbohydrate molecules at times cause slight inhibition.

During the course of these investigations it was hoped that some physiological basis for the separation of some of the groups of the myxobacteria might be discovered. It seems, however, that the carbon requirements of all the species that have been studied are about the same. Certain variations in rates of growth between species have been noted, but these differences are constant regardless of the medium. For example, *Myxococcus virescens* is extremely slow growing compared with *Podangium erectum*, but that relationship is always the same, providing growth is at all possible.

One point of interest is the failure of the cytophagas to attack starch and chitin (Stanier 1940). The myxobacteria are quite able to break down starch, and Johnson (1932) and Benton (1935) both recorded the decomposition of chitin. On the other hand, the cytophagas are able completely to decompose both agar and cellulose. To this author's knowledge no claims of this kind have been made for any of the myxobacteria. Mishustin (1938) showed partial cellulose decomposition by certain species, and the present investigations have indicated utilization of agar and cellulose to some extent; nothing approaching a complete breakdown has been observed. Inasmuch as members of the genus *Cytophaga* are quite similar to the myxobacteria from a morphological standpoint, and since it is possible that the two groups will be merged, these points of distinction might be of value for differentiation on a physiological basis.

The nitrogen metabolism of the group is not well understood. It is possible that the various species are able to fix atmospheric nitrogen in order to satisfy their needs, but this appears questionable; the substrates upon which most species are normally found in the natural environment would ordinarily be high in nitrogenous materials, and nitrogen fixation would be unnecessary. In a suspension of bacterial cells there would probably be sufficient nitrogen in the cell proteins to support normal development of the slime bacteria. In media containing no suspended cells and no added source of nitrogen it is possible that enough of this element may be present in the agar itself to satisfy the requirements of these bacteria. In response to an inquiry by one of the members<sup>2</sup> of this laboratory staff, the Difco Laboratories reported about 0.2 per cent nitro-

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<sup>2</sup> With the permission of Mr. A. A. Anderson.

gen in Bacto agar. If it were available it is conceivable that this amount might be sufficient for the needs of these organisms. The fact that some species are able to grow, rather poorly, it is true, on nothing but a solution of agar in distilled water would lead one to believe that they could utilize the nitrogen of agar as well as the carbon.

#### SUMMARY

The more complex carbohydrates such as cellulose, starch, dulcitol, and inulin are readily utilized by all of the species of the Myxobacteriales that have been studied. Increasing the amounts of these compounds, within limits, produces corresponding increases in rates of growth. More than 1.0 per cent in the media is not always beneficial, and in some cases has been noted to be slightly inhibitory. The pentoses are highly inhibitory to all species, especially in excess of 0.5 per cent concentrations, and the hexoses are only slightly less active, preventing completely, or in large part, the development of both vegetative colonies and fruiting bodies. Di-saccharides have little effect on the growth of these bacteria, neither inhibiting nor stimulating development. The pH of none of the media was lowered sufficiently to give an acid reaction with brom-cresol purple.

Starch, while apparently more favorable to vegetative growth than reprecipitated cellulose, does not encourage the formation of fruiting bodies. Within the area of growth, starch was broken down as indicated by the iodine test. No indication of decomposition of cellulose, other than good growth, was evident either on reprecipitated cellulose or on filter paper. Agar is a possible source of both carbon and nitrogen for the myxobacteria, but no liquefaction, or other sign of partial or complete breakdown, was noted.

The addition of nitrogen, in the form of inorganic salts, to the media had no significant effect on the growth of the species studied. It is possible that sufficient nitrogen was present in the agar to permit good growth.

Aside from the normal intestinal flora the constituents of dung that appear to be useful to the myxobacteria are the undigested long chain carbohydrates such as cellulose, the water soluble parts of dung apparently being of little value to these organisms.

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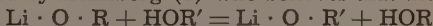
# THE ACTION OF ORGANIC ACIDS ON CORNSTALK LIGNIN<sup>1</sup>

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It is well known that both alcohols (1) and organic acids (2) can be used to extract lignin from plant tissue. Although it is established that lignin isolated from plant tissue by an alcohol is combined with the alkyl group of the extracting alcohol, the mechanism through which the combination occurs has not been proved. Hägglund and Urban (3) reported that a carbonyl group of the lignin molecule forms a semi-acetal with the extracting alcohol. A similar mechanism was proposed by Charbonnier (4) who believes that an acetal is formed between a tautomeric hydroxyl of the lignin and the alkoxy of the alcohol. An entirely different mechanism was proposed by Holmberg (5) who believes that the reaction:



takes place between lignin and the extracting alcohol. It is left undecided whether R consists of hydrogen, a carbohydrate group, another lignin group or even another part of the same lignin molecule. It has been shown that lignin isolated from plant tissue by anhydrous organic acids is obtained as an ester of the extracting acid (2b, 2d, 6). On the other hand Schütz (2e) found that neither chlorine nor carboxyl groups are present in lignin extracted from plant tissue by aqueous solutions of chloroacetic acid.

Since aqueous solutions of organic acids extract lignin from plant tissue but do not combine with the extracted lignin (2e), aqueous solutions of lactic acid, which have been used as solvents for lignin (7), should be of value to test the mechanism through which compounds containing alcoholic hydroxyl groups combine with lignin.

<sup>1</sup>Supported in part by a grant from the Industrial Science Research funds of the Iowa State College for the study of lignin.

- (1) (a) Klason, *Tek. Tid. Kemi Metallurgi*, **23**, 11 (1893); cited by Freudenberg, *Ann. Rev. Biochem.*, **8**, 103 (1939); (b) Hibbert, *Paper Trade J.*, **113**, No. 4, 35 (1941); (c) Hewson, McCarthy, and Hibbert, *J. Am. Chem. Soc.*, **63**, 3045 (1941).
- (2) (a) Pauly, German Patent, 309,551 (1916); cited by Schwalbe, "Die Chemie der Hölzer," Gebrüder Borntraeger, Berlin, Germany, 1939, p. 176; (b) Friedrich, *Z. Physiol. Chem.*, **176**, 127 (1928); (c) Staudinger and Dreher, *Ber.*, **69**, 1729 (1936); (d) Nikitin and Rudneva, *J. Applied Chem. (U.S.S.R.)*, **10**, 1915 (1937); (e) Schütz, *Cellulosechem.*, **18**, 76 (1940).
- (3) (a) Hägglund and Urban, *Cellulosechem.*, **8**, 69 (1927); (b) Hägglund and Urban, *ibid.*, **9**, 49 (1928).
- (4) Charbonnier, *Paper Trade J.*, **114**, No. 11, 13 (1942).
- (5) Holmberg, *Papier-Fabr.*, **36**, Tech. Wies. Tl. 218 (1938).
- (6) (a) Bell, Cramer, Wright, and Hibbert, *Ber.*, **71**, 746 (1938); (b) Spencer and Wright, *J. Am. Chem. Soc.*, **63**, 2017 (1941).
- (7) (a) Hillmer, *Cellulosechem.*, **6**, 169 (1925); (b) Hibbert and Phillips, *Can. J. Research*, **3**, 65 (1930); (c) Gibbs, *ibid.*, **12**, 715 (1935).

## EXPERIMENTAL

*Action of acids on lignin.* Preliminary experiments indicated that organic acid lignins extracted from cornstalks containing pentosans are contaminated with carbohydrate material. Accordingly, all lignin preparations reported in this manuscript were made from cornstalks that had been freed of pentosans by hydrolysis with dilute hydrochloric acid (8). Five-gram samples of air-dried, acid-hydrolyzed, ground cornstalks were

TABLE 1  
ANALYSIS OF ACID LIGNINS

Acid	Temp., °C., of Extraction	Time, Hours, of Extraction	CH <sub>3</sub> O, %
85% Lactic.....	92	4	10.7
	92	8	11.6
	112	0.5	12.0
	112	1	12.0
	112	2	13.6
	112	4	13.5
	112	8	12.4
	112	16	12.7
	112	32	12.3*
	122	4	12.3
	122	8	14.3
	126	4	12.0
85% Propionic....	112	4	8.4
100% Acetic.....	112	4	11.5†

\* The temperature dropped below 112° C. during the night.

† This extraction was catalyzed by the addition of 1 ml. of concentrated hydrochloric acid to the reaction mixture.

digested with 60-ml. portions of organic acids at elevated temperatures for varying lengths of time. Aqueous lactic acid, aqueous  $\alpha$ -methoxypropionic acid (prepared according to the method of Purdie and Irvine (9)), aqueous and anhydrous propionic, acetic, and formic acids were used. Some of the reactions were catalyzed by the addition of 1 ml. of concentrated hydrochloric acid to the extraction liquors. Each sample was then diluted with an equal volume of the corresponding hot acid, filtered, and thoroughly washed with hot acid. The pulp was added to 1 l. of boiling water, allowed to stand over night, filtered, washed with boiling water until the filtrate was free of acid, and air dried. The air-dried pulp was weighed and analyzed for lignin by the cold sulfuric acid method (10). The results obtained are given in Figures 1 and 2.

*Recovery of lignins.* Each filtrate from the acid extractions of cornstalks was cooled and slowly poured into 1.5 l. of distilled water; the water was stirred continuously while the acid solution was added. The precipitated lignin was filtered and washed until the filtrate was free of

(8) Morgal, *This Journal*, **11**, 365 (1937).

(9) Purdie and Irvine, *J. Chem. Soc.*, **75**, 485 (1899).

(10) Peterson, Walde, and Hixon, *Ind. Eng. Chem., Anal. Ed.*, **4**, 216 (1932).

acid. The recovered lignin was dried over phosphoric anhydride in a vacuum desiccator and analyzed for methoxyl (11).

*Action of acids on caustic alkali lignin.* Sodium hydroxide lignin was prepared by treating 2 kg. of air-dried, acid-hydrolyzed ground corn-

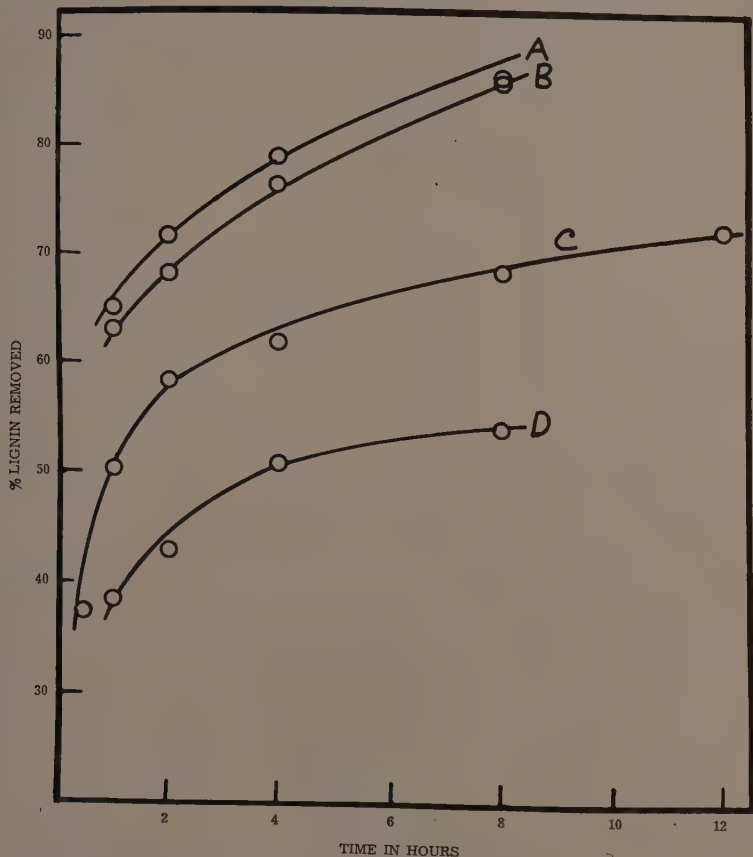


FIG. 1. Lignin extracted with 85 per cent lactic acid. A—126°C.; B—122°C.; C—112°C.; D—92°C.

stalks with 30 l. of 4 per cent aqueous alkali. After standing for 15 hours at room temperature, the insoluble pulp was removed from the alkaline liquor by filtering through cheesecloth. The black liquor was acidified with concentrated hydrochloric acid; the precipitated lignin was filtered,

(11) Johns, "Laboratory Manual of Microchemistry," Burgess Publishing Company, Minneapolis, Minn., 1941, p. 42.

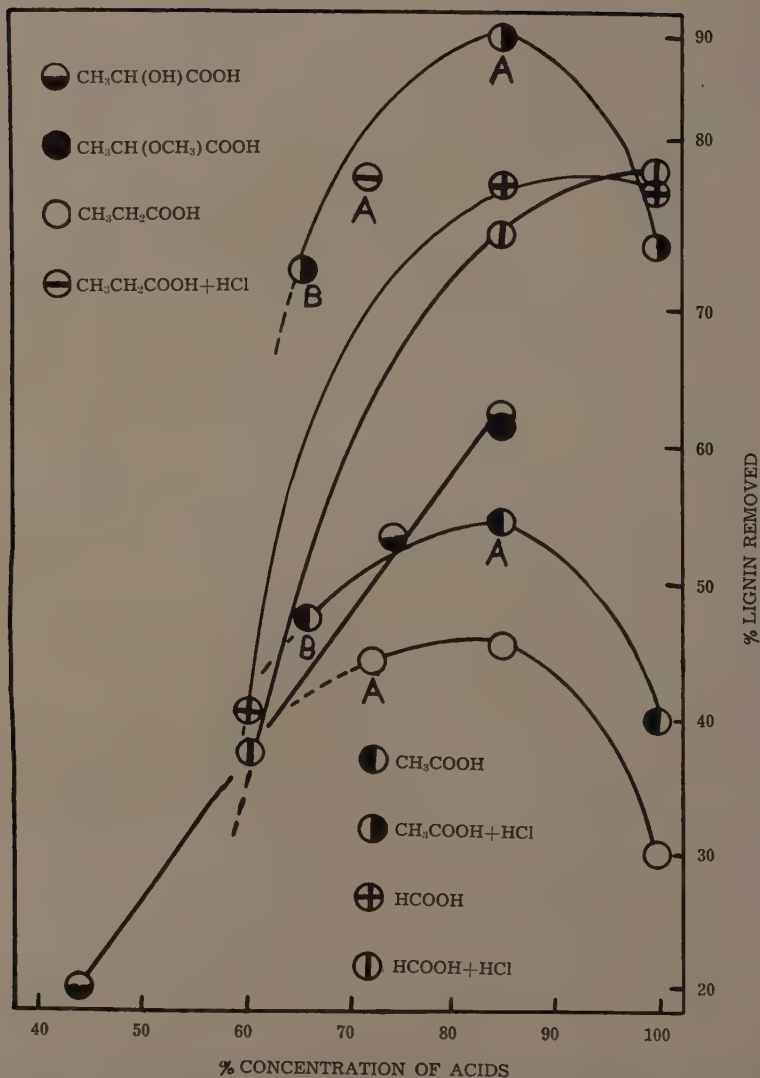


FIG. 2. Lignin extracted with organic acids. Each sample was digested for 4 hours. All extractions with formic acid were at  $100^\circ\text{C}$ .; all other extractions were at  $112^\circ\text{C}$ ., except those labeled A which were at  $105^\circ\text{C}$ ., and those labeled B which were at  $103^\circ\text{C}$ .

washed until the filtrate was free of chloride, dried, and freed of ash by the method of Morgal (8). After drying over phosphoric anhydride the recovered lignin was analyzed for methoxyl (11). One-gram samples of sodium hydroxide lignin were digested for 4 hours at elevated temperatures with aqueous and anhydrous organic acids. The solutions were cooled and filtered; the lignins were recovered by pouring the filtrates into distilled water, filtering, and washing the precipitated lignins. Each sample of recovered lignin was dried, weighed, and analyzed for methoxyl (11).

TABLE 2  
SODIUM HYDROXIDE LIGNIN DIGESTED  
4 HOURS WITH ORGANIC ACIDS

Acid Used	Temp., ° C.	Lignin Recovered, %	CH <sub>3</sub> O, % in Recovered Lignin *
85% Lactic acid.....	112	85	15.0
74.7% Lactic acid.....	112	91	15.1
85% $\alpha$ -Methoxy-propionic acid.....	112	93	17.0
100% Propionic acid.....	112	28†	16.1
72.4% Propionic acid.....	105	84	15.2
100% Acetic acid.....	112	74‡	17.2
66.4% Acetic acid.....	103	84	16.0
100% Formic acid.....	100	78	16.2
60.4% Formic acid.....	100	—§	.....

\* Untreated sodium hydroxide lignin analyzed 15.4 per cent methoxyl.

† Only part of the sodium hydroxide lignin was soluble in hot anhydrous propionic acid.

‡ A small amount of the sodium hydroxide lignin was insoluble in hot glacial acetic acid.

§ Sodium hydroxide lignin was almost completely insoluble in hot 60.4 per cent formic acid.

*Alkaline saponification of lignins.* Samples of lignin weighing 150 mg. were dissolved in 20 ml. of 10 per cent sodium hydroxide solution, heated to boiling, placed on a steam plate, and kept above 90°C. for 2 hours. At the end of this time the samples were cooled, filtered, and diluted to 200 ml. The lignin was precipitated by the addition of a slight excess of hydrochloric acid; the precipitated lignin was filtered, washed, dried, weighed, and analyzed for methoxyl (11).

*Methylation and saponification of lignins.* Lactic acid lignin, sodium hydroxide lignin that had been treated with lactic acid, and untreated sodium hydroxide lignin were methylated with diazomethane. One-gram samples of lignin were passed through a 100-mesh sieve, dried in vacuum over phosphoric anhydride, and placed in 150 ml. Erlenmeyer flasks. An ether solution of diazomethane prepared from 2 ml. of nitrosomethylurethane (12) was poured over each sample and allowed to stand over night. The ether was filtered off, and each lignin sample was washed with low-boiling petroleum ether (Skelly A). The lignin samples were subjected to another methylation similar to the above but using only 1 ml. of nitromethylurethane to generate the diazomethane. The twice methyl-

(12) Hickinbottom, "Reactions of Organic Compounds," Longmans, Green and Co., London, England, 1936, p. 331.



TABLE 3  
 ALKALI SAPONIFICATION OF LIGNINS

Type of Lignin	CH <sub>3</sub> O, % Before Saponification	Lignin Recovered, % After Saponification	CH <sub>3</sub> O, % After Saponification
Lactic acid lignin, prepared by boiling stalks with 85% lactic acid for 8 hours.....	13.5	78	15.7
Lactic acid lignin, prepared by digesting stalks with 85% lactic acid for 4 hours at 112° C.....	12.3*	79	14.7
Lactic acid lignin, prepared by digesting stalks with 74.7% lactic acid for 4 hours at 112° C.	12.6	73	14.9
Lactic acid lignin, prepared by digesting stalks with 85% lactic acid (catalyzed by 1 ml. concentrated hydrochloric acid) for 1 hour at 112° C.....	12.4	77	12.3
Sodium hydroxide lignin.....	15.4	83	16.7
Sodium hydroxide lignin, digested 4 hours at 112° C. with 85% lactic acid.....	15.0	82	16.4
Sodium hydroxide lignin, digested 4 hours at 112° C. with 74.7% lactic acid.....	15.1	74	16.1
$\alpha$ -Methoxypropionic acid lignin..	12.3	70	14.3
Sodium hydroxide lignin, digested with $\alpha$ -methoxypropionic acid..	17.0	78	15.5
Propionic acid lignin, prepared by digesting stalks 4 hours at 112° C. with 100% propionic acid...	10.2	76	14.5
Propionic acid lignin, prepared by digesting stalks 4 hours at 105° C. with 72.4% propionic acid...	12.5	71	12.5
Sodium hydroxide lignin, digested 4 hours at 112° C. with 100% propionic acid.....	16.1	75	16.3
Sodium hydroxide lignin, digested 4 hours at 105° C. with 72.4% propionic acid.....	15.2	74	16.1
Acetic acid lignin, prepared by digesting stalks 4 hours at 112° C. with 100% acetic acid.....	10.2	76	15.4
Acetic acid lignin, prepared by digesting stalks 4 hours at 103° C. with 66.4% acetic acid.....	13.6	72	14.3

Table 3—continued

Type of Lignin	CH <sub>3</sub> O, % Before Saponification	Lignin Recovered, % After Saponification	CH <sub>3</sub> O, % After Saponification
Sodium hydroxide lignin, treated 4 hours at 112° C. with 100% acetic acid.....	17.2	77	15.8
Sodium hydroxide lignin, treated 4 hours at 103° C. with 66.4% acetic acid.....	16.0	71	14.7
Formic acid lignin, prepared by treating stalks 4 hours at 100° C. with 100% formic acid.....	11.7	74	14.4
Formic acid lignin, prepared by treating stalks 4 hours at 100° C. with 60.4% formic acid.....	13.4	73	14.9
Sodium hydroxide lignin, digested 4 hours at 100° C. with 100% formic acid.....	16.2	83	15.9

\* This sample of lactic acid lignin was prepared by digesting 25 g. of cornstalks with 300 ml. of 85 per cent lactic acid for 4 hours at 112° C.

ated samples were methylated a third time and dried in vacuum over phosphoric anhydride. A fourth methylation did not increase the methoxyl content of the thrice methylated lignin samples. The diazo-methane methylated lignins were saponified with sodium carbonate by the method of Ahlm and Brauns (13), dried, and analyzed for methoxyl (11).

TABLE 4  
METHYLATION AND SAPONIFICATION OF LIGNINS

Type of Lignin	CH <sub>3</sub> O, % Before Methylation	CH <sub>3</sub> O, % After Methylation	Lignin Recovered, % After Saponification	CH <sub>3</sub> O, % After Saponification of Methylated Lignin
Lactic acid lignin, prepared by treating stalks with 85% lactic acid at 112° C. for 4 hours....	12.3*	22.4	80	17.5
Sodium hydroxide lignin, treated 4 hours at 112° C. with 85% lactic acid.....	15.0	23.6	85	18.1
Sodium hydroxide lignin.....	15.4	24.8	83	23.5

\* This sample of lactic acid lignin was prepared by digesting 25 g. of cornstalks with 300 ml. of 85 per cent lactic acid for 4 hours at 112° C.

(13) Ahlm and Brauns, *J. Am. Chem. Soc.*, **61**, 277 (1939).

*Acid hydrolysis of lignins.* Several samples of lactic acid lignin, a sample of sodium hydroxide lignin that had been treated with lactic acid, and a sample of untreated sodium hydroxide lignin were hydrolyzed with dilute hydrochloric acid (1 volume of concentrated acid to 4 volumes of water). Lignin samples weighing 250 mg. were covered with 25 ml. of dilute hydrochloric acid, heated to boiling, and kept above 90°C. on a steam plate for 2 hours. The samples were cooled, filtered, and washed until the filtrates were free of chloride. After drying, the acid hydrolyzed lignins were analyzed for methoxyl (11).

TABLE 5  
ACID HYDROLYSIS OF LIGNINS

Type of Lignin	CH <sub>3</sub> O, % Before Hydrolysis	Lignin Recovered, % After Hydrolysis	CH <sub>3</sub> O, % After Hydrolysis
Lactic acid lignin, prepared by boiling stalks 8 hours with 85% lactic acid.....	13.5	91	13.6
Lactic acid lignin, prepared by digesting stalks 4 hours at 112° C. with 85% lactic acid.....	12.3*	93	13.1
Lactic acid lignin, prepared by digesting stalks 1 hour at 112° C. with 85% lactic acid (catalyzed by the addition of 1 ml. concentrated hydrochloric acid).	12.4	82	13.1
Sodium hydroxide lignin.....	15.4	88	16.6
Sodium hydroxide lignin, digested 4 hours at 112° C. with 85% lactic acid.....	15.0	89	16.0

\* This sample of lactic acid lignin was prepared by digesting 25 g. of cornstalks with 300 ml. of 85 per cent lactic acid for 4 hours at 112° C.

#### DISCUSSION

Data presented in Figure 2 show the effect of the presence of hydrochloric acid on the extraction of lignin by a series of organic acids. These data also show that 85 per cent aqueous solutions of formic, acetic, and propionic acids extract more lignin from plant tissues than do the anhydrous acids. The fact that aqueous solutions of formic acid containing hydrochloric acid extract slightly less lignin from cornstalks than do hydrogen chloride free aqueous solutions of formic acid is compatible with the conclusion that condensation-polymerization changes occur when natural lignin is treated with aqueous solutions of formic acid containing hydrochloric acid. It seems possible that a hydrolytic effect, similar to that observed in the alcoholysis of lignin (1c), may play an important role in the extraction of lignin by organic acids. This does not

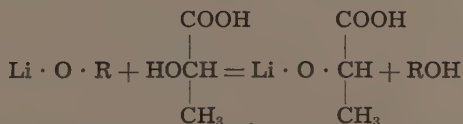
preclude the possibility that organic solvent action may be a factor in the extraction of lignin by anhydrous organic acids.

Methoxyl analyses of lignin extracted from cornstalks by lactic acid indicate that fractionation takes place during the extraction. The fractions first removed have a lower methoxyl content than do the intermediate fractions. The intermediate fractions contain more methoxyl groups than the final fractions.

Alkali saponification studies indicate that anhydrous propionic, acetic, and formic acids form esters with the lignins that they extract. Apparently esterification plays no important role in the extraction of lignin by these acids because maximum extraction of lignin is obtained under conditions that do not favor esterification.

In most cases the action of the organic acids on sodium hydroxide lignin is not clearly revealed by the available data. In all of the reactions investigated, there is evidence of fractionation. The action of most of the acids on isolated lignin is not the same as their action on natural lignin in plant tissues.

The results of diazomethane methylation and sodium carbonate saponification studies on lactic acid lignin, sodium hydroxide lignin that had been treated with lactic acid, and untreated sodium hydroxide lignin presented in Table 4, indicate that lactic acid adds carboxyl groups to lignin. If lactic acid adds to lignin by forming an acetal between a carbonyl (or tautomeric hydroxyl) of the lignin and the hydroxyl of the lactic acid, hydrolysis of the acetal with dilute hydrochloric acid should increase the methoxyl content of the recovered lignin. The data presented in Table 5 show that this result is not obtained. From these facts it seems probable that lactic acid does not form an acetal with lignin. An indication that lactic acid reacts with sodium hydroxide lignin through phenolic groups of the lignin is found in the fact that methylated sodium hydroxide lignin contains a larger percentage of methoxyl than does methylated sodium hydroxide lignin that had been digested with lactic acid before methylation. These data indicate that lactic acid may combine with both isolated and natural lignin according to the mechanism proposed by Holmberg (5) to explain the action between alcohols and lignin. The following equation illustrates the mechanism involved:



In the case of natural lignin it is undecided whether R consists of a hydrogen, a carbohydrate group, another lignin group, or even another part of the same lignin group. In isolated lignin, R is probably the hydrogen of a phenolic hydroxyl. It appears probable that the combination of lactic acid with lignin does not play an important role in the isolation of lignin

from plant tissue; the limited data available do not indicate whether the combination occurs before or after the lignin is extracted.

#### SUMMARY

1. A hydrolytic effect appears to play an important role in the extraction of lignin from plant tissue by organic acids.

2. Data compatible with the conclusion that aqueous solutions of formic acid containing hydrochloric acid may cause lignin in plant tissue to undergo condensation-polymerization reactions are presented.

3. Fractionation takes place when lignin is extracted from plant tissue by organic acids.

4. Anhydrous organic acids form esters with the lignin that they extract. Esterification plays no important role in the extraction of lignin from plant tissue by aqueous solutions of organic acids.

5. Lactic acid adds carboxyl groups to both natural and isolated lignin. It is possible that this acid combines with lignin according to the mechanism proposed by Holmberg (5) to explain the action between alcohols and lignin.

# A SEMI-MICRO METHOD FOR THE DETERMINATION OF REDUCING SUGARS IN FERMENTATION MEDIA<sup>1</sup>

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The quantitative determination of reducing sugars is one of the most frequent estimations required in the field of biochemistry. Such determinations are especially important in fermentation studies to follow the rate of dissimilation of sugars and the yields of products therefrom.

Two types of oxidizing agents have been most successfully employed for the analysis of reducing sugars. Ferricyanide reagents are used in the Hagedorn and Jensen (1) method and its several modifications. Many procedures have been developed employing copper reagents. According to Shaffer and Somogyi (4), Somogyi (5), and Pickett (2), the ferricyanide is less specific in its reaction with sugars than are the copper reagents since the ferric ion oxidizes substances other than the sugars to a greater extent than does the cupric ion. On the other hand, the copper reagents have a disadvantage in that the cuprous oxide formed is subject to partial reoxidation by atmospheric oxygen. In spite of this disadvantage the greater specificity of the copper reagents makes them more suitable for most biochemical studies.

Many methods have been suggested for measuring the amount of cuprous oxide formed, but the iodimetric method of Shaffer and Hartmann (3) is the most convenient and the most widely used in this country. Stiles, Peterson, and Fred (6) adapted the above procedure to the determination of reducing sugars in bacterial cultures both by micro- and macro-methods. The macro-method of Shaffer and Hartmann has been widely used in fermentation studies but possesses several disadvantages, including the cost of reagents and the close attention required for exact duplication of time and rate of heating. Based upon extensive studies of various factors influencing the rate of copper reduction and maximum reduction equivalents, Shaffer and Somogyi (4) reported a micro-modification of the Shaffer-Hartmann method. Later Somogyi (5) further modified the procedure for the micro-determination of sugar in blood filtrates. The micro-methods were designed for the determination of not more than 2 milligrams of sugar in a 5 ml. sample of solution. For the routine analysis of fermentation media it is desirable to be able to determine the sugar in a wider range of concentrations so as to decrease the labor and inaccuracies involved in dilutions and to

<sup>1</sup> This work was supported in part by a grant from the Industrial Science Research funds of the Iowa State College for studies on the fermentative utilization of agricultural products.



prevent the necessity of frequent repetitions of the analyses in order to adjust the concentrations to the narrow range.

The present paper deals with a modification of the Shaffer-Somogyi method to determine a maximum of 11 milligrams instead of 2 milligrams of sugar in 5 ml. of solution. A great deal of experimental work was involved in this adaptation to properly balance the several reagents. As a result of these investigations the following reagents and procedure have been found to be entirely satisfactory for routine analysis of reducing sugar in fermentation media.

#### REAGENTS

The following reagents are employed in the sugar determination:

I. A solution containing 12.5 per cent KI and 25 per cent  $K_2C_2O_4 \cdot H_2O$ .

II. A 7.5 N solution of  $H_2SO_4$ . This solution should be kept free of oxidizable material. Unsaturated material extracted from rubber caused trouble until the source of difficulty was discovered and rubber tubing connections were eliminated.

III. Standard 0.0500 N  $Na_2S_2O_3$  solution.

IV. Starch indicator solution containing 1 per cent soluble starch in a saturated NaCl solution.

V. Sugar reagent "G":

<i>Components</i>	<i>Weight in grams per liter</i>
$CuSO_4 \cdot 5H_2O$ .....	37.5
(Rochelle salt)	
$NaKC_4H_4O_6 \cdot 4H_2O$ .....	125
$Na_2CO_3$ (anhyd.) .....	53
KI .....	1.0
$Na_2SO_4$ (anhyd.) .....	50
$KIO_3$ .....	3.5665 (exactly)
NaOH .....	Approximately saturated solution added to adjust to pH= 9.48

For a detailed discussion of the purpose and effect of the various components of the above reagent, the publications of Shaffer and Somogyi should be consulted. The small amount of potassium iodide has a stabilizing effect and renders the reagent less sensitive to reducing agents other than sugars. The sodium sulfate eliminates the reoxidation of the cuprous oxide, and stabilizes the solution eliminating self-reduction of the reagent; it also depresses the dissociation of the carbonate and thus lowers the alkalinity of the solution. Somogyi (5) called attention to the influence of pH on the sensitiveness of the copper reduction and attempted to control the pH by the use of buffer mixtures of sodium carbonates and bicarbonate. The present authors have found it very

advantageous to adjust the pH to an exact value by adding sodium hydroxide, the pH being determined with the glass electrode.

The "Sugar reagent 'G' " is prepared as follows: The sodium carbonate and Rochelle salt are dissolved in 300 ml. of distilled water after which the copper sulfate, dissolved in about 500 ml. of distilled water, is added with continuous stirring so that no free carbon dioxide is evolved. The use of a funnel with the exit below the surface of the carbonate-tartrate solution is helpful. The potassium iodide and sodium sulfate are added, stirring until dissolved; the solution is then made up to volume of about 960 ml. with distilled water. The strong solution of sodium hydroxide is next slowly added, with stirring, until the pH has reached the value of 9.48. The pH is determined at 25°C. with the glass electrode, the salt error being neglected. The samples used for testing the pH are always returned to the main solution. The resulting solution is heated to boiling and is boiled gently for 10 minutes in a covered container. It is then cooled to 20°C. The potassium iodate, accurately weighed, is added, dissolved completely, and the volume made up to exactly one liter in a volumetric flask.

The reagent when freshly prepared always contains some suspended matter. The solution is therefore allowed to stand for at least a week in a Pyrex container. Soft glass containers must not be used since, as pointed out by Shaffer and Somogyi (4), cuprous oxide continually deposits from the mixture in such containers. After the suspended matter has settled out, the clear solution is filtered through ignited asbestos, or siphoned out, and is stored in a Pyrex bottle. By following the above general procedure autoreduction is reduced to a minimum.

#### PROCEDURE OF ANALYSIS

Exactly 5 ml. of sugar reagent "G" is measured into a 25 × 100 mm. Pyrex test tube. The use of an automatic level refilling pipette has been found most useful for this step in routine analyses. A 5 ml. sample of test solution is pipetted into the tube and thoroughly mixed by shaking. The tube is fitted with a rubber stopper provided with a short piece of capillary tubing. The tube is then immersed (at least two-thirds of its length) in a boiling water bath and is heated for the standard heating time, as indicated below, appropriate for the sugar being determined. The contents of the tube are cooled to about 30°C. by immersion in a cold water bath, 2 ml. of the potassium iodide-oxalate solution (reagent I) added, and the solutions mixed by shaking. To this mixture 1 ml. of the 7.5 N sulfuric acid is carefully added down the side of the inclined tube in such a way as to avoid a too rapid release of carbon dioxide. The best procedure is to incline the tube severely so that considerable surface is formed by the liquid, then allow the acid to flow down the side of the tube and mix by slowly revolving the tube in the inclined position until the first violent evolution of carbon dioxide has subsided; the solution is then mixed thoroughly by shaking. After addition of

the sulfuric acid, sufficient time must be allowed for *all* of the cuprous oxide to dissolve and for the solution to become entirely clear.

The excess iodine is finally titrated with the 0.0500 N sodium thiosulfate, using the starch indicator near the end point. The normality of the thiosulfate solution is checked frequently against 0.0500 N potassium iodate solution. A blank is run in exactly the same manner using 5 ml. of water as the test sample. The difference, corresponding to the volume of 0.0500 N thiosulfate consumed by the cuprous oxide, is converted into milligrams of sugar per 5 ml. of solution by reading from a standardization curve. As will be seen from data presented below, the volume of thiosulfate used is, within reasonable limits, a linear function of the concentration of the sugar. It is desirable to check the reagents periodically against a sample of pure sugar although their value remains remarkably constant over a period of months. This stability is largely associated with the accurate adjustment of the pH of the "sugar reagent 'G'."

When a large number of routine analyses are to be made, a number of samples may be prepared in separate test tubes, heated and cooled together at the same time, and then titrated. Analyses are most satisfactory when the sample contains 1 to 10 mg. of sugar per 5 ml. of test solution. In some fermented media no dilution may be needed. Clarification, however, is recommended for the most accurate work, basic lead acetate being employed. Clarification may be necessary for much routine work, but this matter should be checked for any given fermentation.

#### EXPERIMENTAL

Details have been given above for the preparation of reagents and the general procedure for using the proposed semi-micro method for the determination of reducing sugars in fermentation media. A large amount of experimental work was involved in developing the reagents employed, but there would be little value in presenting the mass of accumulated data here. The procedure has been applied over a period of three years to more than a dozen reducing compounds of interest in fermentation. Typical data are given below for five reducing sugars to illustrate the standardization procedure. Aside from these five sugars other reducing compounds to which the method has been successfully applied include maltose, lactose, *d*-arabinose, *d*-xylose, *l*-rhamnose, dihydroxyacetone and acetyl-methyl-carbinol.

In Table 1 are given data for five typical sugars showing the relation between the time of heating of the sample with the reagents and the reduction values in terms of the volume of standard sodium thiosulfate solution. Each solution contained exactly 10 mg. of pure sugar per 5 ml. of solution.

It is evident that the reduction values reach a maximum steady value which can be accurately determined by means of graphs. A standard

TABLE 1  
RELATION OF TIME OF HEATING AND REDUCING VALUES  
(Ml. of 0.0500 N thiosulfate per 5 ml. of solution containing 10 mg. of sugar)

Sugar	Time of Heating, Minutes					
	10	15	20	25	30	35
<i>d</i> -glucose.....	8.28	8.63	8.68	8.62	8.69	.....
<i>d</i> -mannose.....	6.30	7.60	8.08	8.28	8.35	8.38
<i>d</i> -galactose.....	6.65	7.19	7.29	7.37	7.39	7.39
<i>l</i> -sorbose.....	7.51	7.54	7.57	7.59	7.60	.....
<i>l</i> -arabinose.....	7.19	7.66	7.78	7.81	7.86	.....

heating time of 30 minutes is indicated as sufficient for the sugars tested, although a shorter time might be used with sorbose. The standard heating time should be established by trial for each new reductant tested.

In Table 2 are given the reduction values of five sugars as a function of their concentrations using a standard heating time of 30 minutes.

TABLE 2  
REDUCING VALUES FOR SEVERAL CONCENTRATIONS OF SUGARS  
(Ml. of 0.0500 N thiosulfate per 5 ml. of solution containing varying weights of sugar)

Sugar	Mg. of Sugar per 5 ml. of Solution				
	2	4	6	8	10
<i>d</i> -glucose.....	1.70	3.41	5.14	6.86	8.68
<i>d</i> -mannose.....	1.64	3.34	5.07	6.71	8.43
<i>d</i> -galactose.....	1.46	2.94	4.43	5.91	7.37
<i>l</i> -sorbose.....	1.47	2.97	4.47	6.00	7.56
<i>l</i> -arabinose.....	1.55	3.11	4.66	6.27	7.84

Standardization curves were plotted for each sugar. The curves were found to give nearly straight lines intersecting at the origin. The deviation of the linear relation is so slight that straight lines have been used for routine work in these laboratories.

### SUMMARY

A semi-micro method for the determination of reducing sugars in fermentation media has been described in detail. The procedure has been thoroughly tested in these laboratories for three years in routine analyses with more than a dozen reducing compounds. It has been found entirely satisfactory in every way.

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## NATURE OF EIMERIA NIESCHULZI-GROWTH-PROMOTING POTENCY OF FEEDING STUFFS

### 5. DRY-HEATING INGREDIENTS OF THE RATION<sup>1</sup>

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It has already been observed in this laboratory by Becker and Dilworth (1941) that vitamin B<sub>6</sub> favored the production of increased numbers of oocysts in rats infected with *Eimeria nieschulzi* and on a special ration somewhat restricted in vitamin content when the amount of vitamin B<sub>1</sub> in the ration was markedly limited, but that a pronounced decrease in the number of these stages was effected by supplementing the ration with both vitamins B<sub>1</sub> and B<sub>6</sub>. A similar effect was noted by Becker (1941) when the vitamins were administered parenterally. A later investigation by Becker and Smith (1942) of the behavior of pantothenic acid in the same parasitism has revealed that it has the property of increasing the number of oocysts produced regardless of whether the reference ration was unsupplemented or supplemented with both vitamins B<sub>1</sub> and B<sub>6</sub>. In other words, pantothenic acid may nullify the parasite-growth-inhibiting properties exhibited by combination of vitamins B<sub>1</sub> and B<sub>6</sub> in *Eimeria nieschulzi* infection.

It was first observed by Kline, Keenan, Elvehjem, and Hart (1932) that when a ration of natural foodstuffs was dry-heated at 95°–100°C. for 144 hours and fed to chicks, the chicks developed symptoms of "pellagra," but displayed no evident lack of vitamin B<sub>1</sub>. There followed a considerable number of papers on the nature of the factor destroyed by dry-heating, until Jukes (1939), Wooly, Waisman, and Elvehjem (1939), and Williams (1939) showed that the chick "antidermatitis factor" appeared to be identical with pantothenic acid.

The rats used in the present experiment were raised with their mothers on a ration of yellow corn meal, soybean oil meal, linseed oil meal, wheat middlings, alfalfa meal, dry skimmilk, salt, fine limestone, and cod liver oil concentrate until the litters averaged in the neighborhood of 70 gm., at which time they were separated from their mothers, placed on screens, and started on the following ration, in parts by weight: beet sugar, 52; unextracted casein, 20; wheat middlings (gray shorts), 20; normal salt mixture (Harris), 3; lard, 4; cod liver oil, 1. There were two ingredients of the ration which might be expected to contain pantothenic acid—casein and wheat middlings. According to Jukes (1941) wheat middlings contains from 10–14 µgm. of pantothenic acid per gram, and

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commercial casein, 0.9  $\mu$ gm. per gram. The casein used by us, however, was the "fine" grade and probably contained considerable amounts of whey, which is comparatively rich in pantothenic acid. Thus it seemed that the experimental ration as formulated would lend itself to testing the effect of dry-heating of two of its ingredients without seriously disturbing its vitamin content otherwise. The method of procedure was essentially the same as previously described. The 17-day weight gain recorded for a rat was the greatest gain it made during the first 17 days on the experimental ration.

#### EXPERIMENTAL DATA

1. Effect of dry-heating the middlings. There were five paired groups of rats in this experiment. The reference series received the experimental ration with unheated casein and middlings, while the middlings in the ration offered the test series had been dry-heated in an electric oven at 105°–110°C. for 6 days. Following our customary practice, the rats of the two series were on their respective rations for 10 days before experimental infection with the sporulated oocysts of *Eimeria nieschulzi*. The pertinent data appear in Table 1. It will be noted that in all tests the mean numbers of oocysts eliminated by the reference group far exceeded those of the test group. Also, the mean 17-day weight gains for the groups of the reference series exceeded in every test those of the test series. In fact, it has been our experience that the reference ration, even when fed for many weeks, provides excellent growth for rats. Decreased growth on the ration with heated middlings appears to be due to the destruction of its pantothenic acid.

Mere examination of the differences between the oocyst counts for tests and controls quite convinces one that they are significant; yet because

TABLE 1  
SHOWING EFFECT OF DRY-HEATING OF MIDDINGS ON NUMBERS OF OOCYSTS ELIMINATED  
AND WEIGHT GAINS (NUMBER OF RATS IN GROUPS IN PARENTHESES)

Test No.	Mean No. Oocysts Eliminated in Millions		Mean 17-day Weight Gain	
	Tests	Controls	Tests	Controls
1.....	22.40 (5)	71.0 (5)	50	53
2.....	4.33 (3)	27.3 (3)	34	58
3.....	0.25 (4)	50.0 (4)	36	48
4.....	45.30 (3)	343.0 (3)	46	53
5.....	99.20 (4)	182.5 (4)	49	57

the individual groups in each series are so lacking in uniformity, the method of determining significance of difference of means by small sample methods is excluded. The statistical treatment that seemed to lend itself best for the data was Fisher's (1932, pp. 97–99) method of combining probabilities from tests of significance. In this way a P-value between 0.01

and .001 was obtained, indicating a highly significant difference between tests and control series.

2. Effects of dry-heating the casein. The casein supplied to the test rats in this experiment was subjected to the same heating process as the middlings in the previous experiment. There were eight paired groups, of which those in the reference series received unheated crude casein and unheated middlings while the tests received dry-heated casein and unheated middlings. The data, summarized in Table 2, showed that in seven of the tests, mean numbers of oocysts eliminated by the control rats far exceeded those by the test rats, while in one case the mean for the two groups was practically the same. If the chances are equal, the probabilities of obtaining seven positives and one negative out of eight trials is a little less than .031. Utilizing the previously mentioned Fisher method, a probability of less than .001 was obtained. Therefore the differences may be regarded as significant. In six of the eight trials the mean weight gain of the controls exceeded that of the tests while in the other two there were but small differences.

3. Effect of dry-heating part of casein. Because such striking depressions in oocyst counts had been obtained by heating all the casein in the test ration, it was of interest to know if heating half the casein would produce a similar effect.

In the first experiment the control ration was the same as before, but 10 parts of the casein received by the tests were heated, while 10 parts were the crude untreated. The mean oocyst counts in millions for paired groups (numbers of rats appear in parentheses) of control and test series in separate tests were as follows: 75.6 (5) and 42 (5), respectively; 47.5 (2) and 29 (3); 85.67 (3) and 23 (3). Seventeen-day weight gains for

TABLE 2

SHOWING EFFECT OF DRY-HEATING CASEIN ON NUMBERS OF OOCYSTS ELIMINATED AND WEIGHT GAINS (NUMBER OF RATS IN GROUPS IN PARENTHESES)

Test No.	Mean No. of Oocysts Eliminated in Millions		Mean 17-day Weight Gain	
	Tests	Controls	Tests	Controls
1.....	12.0 (4)	28.5 (4)	53	47
2.....	38.5 (4)	189.7 (4)	51	55
3.....	27.0 (2)	125.5 (2)	54	60
4.....	105.6 (3)	197.5 (2)	41	50
5.....	16.5 (2)	66.6 (3)	38	47
6.....	63.7 (4)	63.2 (4)	34	33
7.....	58.1 (4)	135.5 (4)	55	73
8.....	11.3 (3)	122.6 (3)	62	76

the tests in the same order were: 60 and 65; 46 and 51; 56 and 49. Thus in the three cases the control rats outyielded the tests in oocyst production. The differences are significant when the data are analyzed by the previously mentioned Fisher method. There were but slight differences in 17-day weight gains.

A second experiment was performed in which the control ration remained as before, but the test ration was modified so that it contained 20 parts of heated casein, 20 parts of untreated crude casein, and 32 parts of sucrose in addition to the other usual ingredients. There were five tests in this experiment, for which the oocyst counts (millions) of the paired groups, controls, and tests, respectively, were as follows: 173 (3) and 29 (3); 176 (4) and 127 (4); 178 (6) and 42 (6); 215 (5) and 275 (5); 333 (6) and 180 (6). The same for 17-day weight gains: 56 and 43; 56 and 41; 59 and 50; 70 and 50; 66 and 46. The probability of getting one negative and four positives in five trials with chances equal is about 0.156, which in itself is of but slight significance, but when the data were treated by analysis of variance a significant F-value was obtained.

A third experiment was performed in which the control ration was made up with 40 parts of untreated casein and 32 parts of sucrose instead of 20 parts and 52 parts, respectively, and the test ration was as in the experiment immediately preceding this. Thus the total proportion of casein in the two rations was the same, but half that in the test was dry-heated. There were three tests with paired control and test groups, respectively, which yielded mean numbers of oocysts (millions) as follows: 109 (4) and 41 (4); 151 (5) and 67 (5); 86 (5) and 43 (5). The same for 17-day weight gains: 65 and 60; 50 and 37; 64 and 55. Thus, again, the recipients of heated casein yielded considerably fewer oocysts than the recipients of the unheated casein. While the F-value obtained by analysis of variance was too low to indicate much significance, nevertheless the results seem to be in the direction one could expect from the results of the two preceding experiments.

4. Effect of supplementing heated-casein ration with pantothenate. In order to determine whether the effect of dry-heating the casein, as expressed in depressed mean oocyst counts, might be attributable, at least in large part, to destruction of pantothenate, both test and reference series received the test ration made up with 20 parts of dry-heated casein, while the test series in this case received a supplement of 200  $\mu$ gms. of calcium pantothenate every other day in 2 cc. of water injected directly into its stomach through a rubber tube. The mean counts in millions for test and reference series were, respectively: 300 (4) and 13 (4); 323 (4) and 98 (4); 312 (5) and 109 (5); 343 (6) and 224 (6). Number of rats in each group appears in parentheses. The weight gains for the same lots were 59 and 51, 70 and 58, 59 and 57, 56 and 54. So in all four tests, involving in all nineteen rats in the test and the same number in the reference series, the recipients of pantothenate far outyielded the non-recipients. Analysis of variance shows the two series to be significantly different. It might be assumed that destruction of pantothenate in casein by dry-heating had much to do with the depressed oocyst counts, for restoring that substance markedly raised the counts.

5. Effect of substituting vitamin-free casein for heated casein. It would be, of course, highly desirable to know whether the effects brought about by heating the casein were due to mere destruction of a substance

that in some way favored oocyst production, such as pantothenic acid, or to a positive property conferred upon the casein by dry-heating. The experiments in which both crude and heated casein were received by test series might be interpreted either way, so in order to obtain more evidence on this point three tests were made in which the 20 parts of casein in the control ration were of the crude type and the same amount in the test ration was vitamin free ("Casco"). The mean numbers of oocysts obtained in control and test series in 3 groups were as follows (numbers of rats in parentheses): 84.3 (3) and 61.6 (3); 139.2 (5) and 22 (5); 148.5 (4) and 27 (4). The same for 17-day weight gains; 66 and 25; 73 and 33; 68 and 37. The F-values obtained from analysis of variance of oocyst counts indicated a highly significant difference in the 2 series. The differences in weight gains were also much greater than in the tests involving heated casein. The explanation is that "Casco" casein is almost vitamin-free, while the heated casein retained considerable amounts of all its vitamins except pantothenic acid, and perhaps, vitamin K. Sufficient amounts of the latter for blood coagulation were supplied by the unheated middlings. Also, it is believed that vitamin K is synthesized by microorganisms in the rat's digestive tract.

#### DISCUSSION

The method of dry-heating feeding stuffs in order to destroy pantothenic acid has been utilized to check the previous work which showed that pantothenic acid in the ration, even in the presence of the other vitamins, favors the production of oocysts in *Eimeria nieschulzi* infection of the white rat. This different approach to the problem made it possible to feed considerable amounts of crude casein with heated wheat middlings, or considerable amounts of unheated wheat middlings with heated crude casein, thus manipulating the pantothenate content of each ingredient of the ration, but not materially affecting the other vitamins present. Also, heating half of one ingredient, crude casein, was practiced. In all these experiments the results were in conformance with the hypothesis that reducing the amount of pantothenic acid in the ration would reduce the output of oocysts—at least within limits.

The critical test was that in which both series received heated casein, but one received in addition pantothenate supplement. The response, as expected, was increased oocyst output by the recipients of pantothenate.

Thus it seems established that pantothenic acid definitely favors the elimination of increased numbers of terminal stages, oocysts, in infections of *E. nieschulzi* when other conditions, including size of infective dose, are comparable. The check used to eliminate the possible objection that decreased counts may have been due to a new positive property conferred upon the ration by the heating process was that of feeding vitamin-free casein in place of the dry-heated crude casein. In this case, also, the results in general conformed to those previously obtained, except that rat growth was not so good.

## CONCLUSIONS

1. Dry-heating either the wheat middlings or the crude casein, or half of the crude casein, in a ration with but these two protein-containing ingredients, significantly reduces the number of oocysts eliminated by rats during *E. nieschulzi* infection.

2. Feeding pantothenate to rats receiving dry-heated crude casein in the ration significantly increases the numbers of oocysts eliminated.

3. The substitution of vitamin-free casein for dry-heated crude casein produces practically the same effect as dry-heated casein on numbers of oocysts eliminated, but the rats do not grow so well.

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# VARIABILITY OF NIGROSPORA ON MAIZE<sup>1</sup>

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*Nigrospora* as it occurred on maize in Iowa during the seasons 1938 to 1941 showed wide variability on the host and in pure culture. Mason, in his monograph of the genus (6), erected three species characterized by spore size. Two of these species, *Nigrospora oryzae* (B. and Br.) Petch and *N. sphaerica* (Sacc.) Mason, occurred on the maize collections examined by Mason. Spore measurements of 15 to 20 $\mu$  for this organism, under the generic name *Coniosporium*, were reported by Bubak and Kosaroff (2) in Bulgaria. Measurements of 13 to 18  $\mu$  were recorded by Durrell (4), who employed the generic name *Basisporium*. These measurements would include both of Mason's species. A range of 9 to 16  $\mu$  for 200 spores, which indicated that the specimens would fall in *N. oryzae*, was reported by Savulescu and Rayss (13) in Rumania. Large spores from field collections were observed by Reddy (11) to produce small spores in culture. Variability of spore size in relation to environmental factors has been observed in several genera in the Imperfecti and elsewhere. Nutrition accounted for difference in spore size in *Cytosporina*, *Phomopsis*, and *Diaporthe*, according to Das Gupta (3) and Nitimargi (9). The length of conidia of several species of *Fusarium* was found to vary in response to light and to media in observations made by Harter (5). Separation of species of *Nigrospora* on the basis of spore size apparently cannot be justified until corresponding differences in cultural characteristics and in pathogenicity are established.

This paper is a report of a study of the variability of *Nigrospora* as it occurred on maize and in culture.

## VARIATIONS IN SPORE SIZE OF NIGROSPORA IN FIELD COLLECTIONS

In establishing the species *N. oryzae* and *N. sphaerica*, Mason (6) examined twenty collections of the fungus on monocotyledonous hosts. Four collections were from maize. He also recorded measurements for nine collections on diverse hosts which, in the absence of type material, might with certainty be referred to these two species. Within each species the average spore diameter for the collections examined varied considerably, *N. oryzae* from 13.5 to 14.9  $\mu$  and *N. sphaerica* from 16.5 to 17.8  $\mu$ . The differentiation of two species on the basis of spore measurements alone

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with such a limited number of specimens appeared to be somewhat unwarranted.

To survey further the range of spore sizes, mature spores from field collections of *Nigrospora*-infected maize tissue were measured over a four-year period. Because the spores were oblate-spheroidal in shape, measurements were made of the greater diameters. The average spore diameters for the specimens examined are tabulated in Table 1. For each specimen fifteen spores were measured in 1938, and thirty in 1939, 1940, and 1941. The measurements upon which Mason based his conclusions are included for comparison.

None of the spore sizes of the collections made in 1939 fell within the spore size range of *N. sphaerica*. In each of the four years collections were made in which the spore diameters lay outside the ranges of either *N. oryzae* or *N. sphaerica* as described by Mason. If species were to be differentiated on the basis of spore size alone, it would be necessary to establish new species for such collections. There was a slight tendency toward a bimodal distribution of average spore measurements in specimens collected in 1940 and 1941. With such a wide range of spore measurements, this bimodal effect became of doubtful significance. The possibility that environmental factors or strain differences might be the cause of the slight tendency toward a bimodal distribution in 1940 and 1941 was suggested by the absence of such a distribution in 1939.

#### SOME CHARACTERISTICS OF NIGROSPORA ON THE HOST AND IN CULTURE

Reddy (11) observed that isolates obtained from field collections with large spores often yielded small spores when grown in pure culture. To obtain a better understanding of the behavior of the fungus in pure culture, studies were made of a large number of spore-mass and single-spore isolates.

Spore-mass isolations were made from collections obtained in 1940. Two series of collections were selected, one with average spore diameters exceeding 16  $\mu$ , the other with average diameters less than 14  $\mu$ . Isolations from infected maize kernels were made by surface sterilizing the kernels and dropping them on agar slants. This practice, however, could not be employed with cob segments, arrested axillary shoots, and such tissues, the spongy nature of which made surface sterilization impossible. With such tissues the following technique was employed. A sterile glass cylinder, 2 or 3 centimeters in diameter, with a notch ground into the lower rim, was placed in a sterile Petri dish. Potato-dextrose agar adjusted to pH 5.2 was then poured into the dish. The notch on the cylinder enabled the agar to flow under the lower rim. A segment of infected tissue was then placed inside the cylinder and the dish held at 20°C. for two to four days. Under these conditions *Nigrospora* usually grew out of the cylinder more rapidly than the contaminants, although at times the culture had to be freed of contaminants by repeating the process.

Spore size in culture as compared with that on infected maize tissue, together with records of locality of the collection and mycelial color in

TABLE 1  
DISTRIBUTION OF AVERAGE\* SPORE DIAMETERS OF NIGROSPORA ON MAIZE IN 1938 TO 1941, INCLUSIVE,  
COMPARED WITH COLLECTIONS EXAMINED BY MASON

Collections		Intervals in Microns										
Year	No.	12.6- to 13.0	13.1 to 13.6	13.6 to 14.0	14.1 to 14.5	14.6 to 15.0	15.1 to 15.6	15.6 to 16.0	16.1 to 16.5	16.6 to 17.0	17.1 to 17.5	17.6 to 18.0
1938.....	20	.....	1	.....	1	8	4	5	.....	.....	.....	1
1939.....	78	.....	.....	3	40	26	7	2	.....	.....	.....	.....
1940.....	120	1	6	30	42	13	0	5	8	8	5	2
1941.....	76	.....	5	23	27	6	1	3	3	5	3	.....
Mason's collections....	20	.....	2	5	1	1	0	0	2	1	4	4

\* For each specimen 15 spores were measured in 1938, and 30 in 1939, 1940, and 1941.

culture, is summarized in Table 2. Isolates from collections with large spores, with few exceptions, tended to produce smaller spores in culture than in infected maize tissues and were more variable in color of the mycelium and in average spore diameters than isolates from collections with small spores. The latter tended to produce slightly larger spores in culture than in infected maize tissues. Locality of collection appeared to have no relation to spore size.

TABLE 2  
DIAMETER OF SPORES ON INFECTED MAIZE TISSUE AND IN CULTURE,  
AND COLOR OF THE MYCELIUM IN CULTURE

Collection Number	Locality (Iowa)	Average Diameter of 30 Spores in Microns		Color of Mycelium In Culture
		Maize Tissue	Culture	
L 1.....	Nevada	16.3	16.8	Light gray
L 2.....	Nevada	17.6	none	White
L 3.....	Jewell	17.3	17.1	Tan gray
L 5.....	Nevada	16.5	14.2	Medium gray
L 6.....	Jewell	17.2	15.7	White
L 8.....	Jordan	17.1	16.0	Light gray
L 9.....	Nevada	16.3	14.8	Medium gray
L 11.....	Ankeny	16.7	16.6	Light gray
L 12.....	Ankeny	16.7	16.7	" "
L 13.....	Jewell	17.4	15.5	" "
L 14.....	Nevada	16.7	15.7	" "
L 15.....	Nevada	16.6	17.5	White
S 1.....	Nevada	13.8	14.6	Medium gray
S 2.....	Ames	13.5	14.1	" "
S 3.....	Ames	13.6	14.2	" "
S 4.....	Nevada	13.8	14.7	" "
S 6.....	Gilbert	13.8	13.7	" "
S 8.....	Ankeny	13.5	14.9	" "
S 9.....	Nevada	13.6	14.3	" "
S 10.....	Nevada	13.7	14.2	" "
S 12.....	Jordan	13.7	14.4	Black
S 13.....	Nevada	13.8	13.9	Medium gray
S 14.....	Jewell	13.7	14.7	" "
S 15.....	Nevada	13.8	15.0	" "

There was a possibility that the infection in the maize tissues did not originate from a single strain of the fungus; therefore, single-spore isolations were made from infected maize tissues and from certain of the isolates described in Table 2. Because strains producing large spores in maize tissues tended to produce small spores in culture, inoculum with large spores was selected. The physical and cultural characteristics of this fungus made it comparatively simple to obtain single-spore isolates. The spores were easily seen because they were black, opaque, and relatively large. The mycelium grew rapidly under a glass barrier in agar culture, simplifying freeing the mycelium from contaminants. In practice, a portion of the inoculum from which the single spores were to be taken was agitated with 1 or 2 ml. of water and the suspension of spores

poured on the surface of a potato-dextrose agar film, pH 5.4, of about 1 mm. thickness, retaining with the inoculum as much debris as possible. After removal of the excess water from the surface of the agar, small portions of the agar were transferred to a microscope slide and cut into blocks approximately 2 mm. square. The surface of each block was examined under the microscope, and those blocks were selected with no mycelial fragments and with a single spore, which was measured in situ at this point. These blocks of agar were transferred to the inside of short glass cylinders arranged in Petri dishes containing potato-dextrose agar, pH 5.4, according to the method previously described. The petri dishes were held at 20°C. Successful germination was obtained of 75 per cent of the single spores isolated by this method.

The results of these experiments (Table 3) show a marked tendency for these single-spore isolates, all originating from large spores, to pro-

TABLE 3

VARIATION IN SIZE AND IN CULTURAL CHARACTERISTICS OF SINGLE-SPORE ISOLATES DERIVED FROM LARGE-SPORED COLLECTIONS

Source of Spores	Single-Spore Isolate No.	Spore Diameters in Microns			Color Mycelium, Culture	Time of Sporulation
		Original Culture or Collection, Average 30 Spores	Single Spore	Culture, Average 30 Spores		
Culture L 6*	1.....	15.7	17.8	14.1	Light gray	2 days
Culture L 11*	1.....	16.6	17.8	13.9	Light gray	2 days
	2.....		20.6		White	No spores, 10 days
Culture L 12*	1.....	16.7	17.1	13.7	Medium gray	2 days
	2.....		17.4	14.2	Very dark gray	2 days
	3.....		14.1	13.4	Medium gray	2 days
	4.....		19.2	14.3	Light gray	4 days
Collection 1	1.....	17.8	17.8	14.9	Dark gray	2 days
	2.....		17.4	14.3	Dark gray	2 days
	3.....		17.8	14.2	Dark gray	2 days
Collection 2	1.....	17.2	20.3	14.5	Medium gray	2 days
	2.....		17.8	14.2	White	7 days
	3.....		18.1	15.6	Light gray	7 days
	4.....		17.8	14.2	White	7 days
	5.....		17.1	13.7	White	5 days
	6.....		17.8	15.5	White	10 days
	7.....		17.4	14.5	White	7 days
Collection 3	1.....	17.6	18.9	15.0	Medium gray	2 days
	2.....		18.9	14.4	Medium gray	2 days
	3.....		19.6	14.3	Medium gray	2 days

\* Isolates described in Table 2.

duce spores characteristic of *N. oryzae* in size. The time required for spore production varied from 2 to 10 days, with one isolate producing no spores in 10 days. The variation in color of mycelium, from white to very dark gray, indicated further variability in the fungus.

In comparing single-spore isolates from infected maize tissues, or from isolates of these tissues, the possibility that the source of spores did not originate from a single strain was not eliminated. If single-spore isolates were obtained from monosporic cultures, any variability among isolates might be due to variability inherent in the fungus strain. With the same method as used above, a series of such isolations was made from four of the isolates described in Table 3.

The characteristics of the isolates obtained are described in Table 4. All the spores were small in culture with little variation in average spore diameters, but the color and appearance of mycelium varied considerably. Color of the mycelium ranged from white to almost black. Sporulation varied from abundant to none at the end of 14 days. In many previous isolates with white mycelium, sporulation was scant or lacking. The cultural characteristics of nonsporulating isolates, however, resembled those of scantily sporulating isolates so closely as to enable anyone familiar with the fungus to identify it. The single-spore isolates from collection 2, isolate 6, were of special interest because of the extreme variation in three of the four isolates. These are shown in Figure 1. Two of the four isolates were similar, with white mycelium arranged in whorled tufts pointing away from the center of the Petri dish. One of the two remaining isolates was white without pronounced tufting of the mycelium. On none of these three isolates were spores found after two weeks. The fourth isolate sporulated freely in two days, and had a low, gray, sparse mycelium.

From the data summarized in Tables 2, 3, and 4, it is apparent that the average diameter of spores tended to become fairly uniform in culture, especially in single-spore isolates, and that *Nigrospora* isolates were extremely variable in respect to color and appearance of the mycelium and in rapidity and abundance of sporulation.

In *Nigrospora* isolates the extremes in color of mycelia might be designated the white and gray strains. The gray strains tended to have a depressed or cobwebby mycelium which was never arranged in tufts. Sporulation in the gray strains was always abundant and frequently occurred in 48 hours. This strain was more abundant in years of normal summer rainfall. Seventy-six of the seventy-eight isolates examined in 1939 were gray. The white strains had a cottony mycelium, which was sometimes tufted. Sporulation in culture was sparse and slow, often occurring after three weeks or more and sometimes not at all. In the dry season of 1936, twenty-three of forty isolates were white. Intermediate forms were found, however, which indicated that these two color strains should be considered merely as extremes in a variable population. Two isolates obtained in 1939 were characteristic of the white strain except that they sporulated rather freely in 4 and 6 days, respectively. Both

white and gray strains were obtained as single-spore isolates from a monosporic culture.

#### VARIABILITY OF NIGROSPORA ISOLATES IN RESPONSE TO DIFFERENT CULTURE MEDIA

It was found that four isolates when grown on a series of media varied in their responses to these media. The data from three replications of one such experiment are recorded in Table 5. The media used in this test were as follows: (1) whole milk combined with 2 per cent of agar agar and the fluid portion used with small pieces of the casein coagulated by auto-

TABLE 4  
VARIATION IN CULTURAL CHARACTERISTICS OF SINGLE-SPORE ISOLATES  
DERIVED FROM MONOSPORIC CULTURES

Source of Spores*	Single-spore Sub-isolate Number	Spore Diameters, in Microns		Color Mycelium	Appearance of Mycelium	Sporulation
		Single Spore	Culture, Average 30 Spores			
Culture L 6, isolate 1	1.....	13.9	14.0	Black	Low, sparse	Abundant
	2.....	16.0	14.0	Light gray	Cottony	"
	3.....	13.2	14.2	" "	"	"
	4.....	13.5	14.0	" "	"	"
	5.....	14.2	14.1	" "	"	"
	6.....	14.2	14.2	" "	"	"
Culture L 11, isolate 1	1.....	13.5	13.9	Medium gray	Low, compact	"
	2.....	15.0	13.8	Light gray	" "	"
	3.....	15.3	14.0	" "	" "	"
	4.....	14.2	13.9	Medium gray	" "	"
	5.....	17.1	13.8	" "	" "	"
	6.....	13.5	14.3	" "	" "	"
	7.....	14.2	13.9	" "	" "	"
	8.....	15.0	14.0	" "	" "	"
	9.....	15.0	14.0	Dark gray	" "	"
	10.....	13.5	14.0	Light gray	Cottony	"
Culture L 12, isolate 2	1.....	14.2	13.8	" "	" "	"
	2.....	15.0	14.3	Almost white	Sparse	Sparse
	3.....	13.5	14.2	Almost black	Low, compact	Abundant
	4.....	14.6	13.8	Light gray	Cottony	"
	5.....	13.2	13.5	Medium	Low, compact	"
	6.....	15.7	13.4	White	Fluffy	"
Collection 2, isolate-6	1.....	17.8	.....	White	Tufted	No spores†
	2.....	13.5	.....	"	Cottony	" "
	3.....	14.6	.....	"	Tufted	" "
	4.....	16.4	14.2	Gray	Low, sparse	Abundant‡

\* Isolates described in Table 3.

† No spores formed in 14 days.

‡ Abundant in 2 days.



claving, (2) 1 per cent dextrose, (3) 1 per cent xylose, and (4) 1 per cent peptone, the last three nutrients in Czapek's nutrient solution with 2 per cent agar agar. All cultures were maintained in Petri dishes at 20°C. and examined after 14 days. At the end of this time all the isolates had covered the media except No. 12, which covered approximately a third of the surface of each medium. The appearance and color of the mycelium, rate of sporulation, and rate of growth of these isolates on the four media varied both with the substrate and with each other.

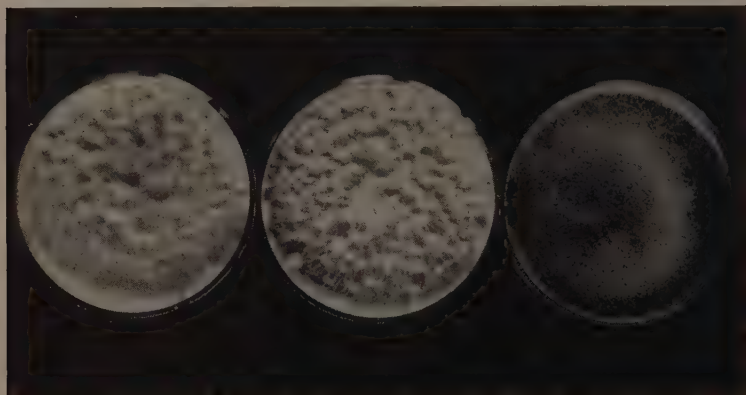


FIG. 1. Variability in cultural characteristics of single-spore isolates. Left to right, isolates No. 2, 1, and 4 of the single-spore isolates derived from collection 2, isolate 6 (Table 3). Isolate No. 2 was white, cottony, and showed no tendency to produce pronounced tufts. Isolate No. 1 was white and tufted, the tufts tending to point away from the center of the culture. Neither of these two isolates had produced spores in 14 days. Isolate No. 4 was low, sparse, and dark, and sporulated freely in 2 days.

#### RELATION OF SPORE SIZE TO INFECTED MAIZE TISSUES

If *Nigrospora* strains producing large spores on maize were to be assigned to one species and strains producing small spores to another, in accord with Mason's (6) proposal, it would be expected that differences in parasitism might be associated with differences in spore size. Observations extending over four years relating to cob maturity and variation in disease symptoms afforded no evidence supporting the presence of large and small-spored species of *Nigrospora*.

Single-spore isolates from large-spored collections have been shown to produce small spores in pure culture. An experiment was arranged to ascertain whether such isolates would again produce large spores if transferred to maize cob. Nine single-spore isolates originally derived from large-spored collections but with average spore diameters in culture ranging from 13.5 to 14.1 $\mu$  were used to inoculate unsterilized sections of cob. These were held in a moist chamber at room temperature for a few days, and measurements were made on 30 spores taken from each of the infected cobs. The average of all spores in culture was 13.9 $\mu$ , and

in the infected cobs,  $14.1\mu$  with a range of  $13.9$  to  $14.3\mu$ . Under the conditions of the experiment the single-spore isolates derived from collections with large spores failed to produce large spores when grown on unsterilized cobs.

TABLE 5

VARIABILITY OF COLOR OF MYCELIUM, TYPE OF MYCELIUM, AND SPORULATION OF FOUR NIGROSPORA ISOLATES ON A SERIES OF MEDIA

Isolate Number	Color, Potato-Dextrose Agar	Nutrient in Agar Agar	Mycelium		Sporulation
			Color	Habit	
19	Gray	Milk Dextrose Xylose Peptone	White	Cottony	Abundant
			Gray	Sparse	"
			"	"	"
38-37	Gray	Milk Dextrose Xylose Peptone	White	Cottony	Sparse
			Gray	Sparse	Abundant
			"	Fluffy	"
12	White	Milk Dextrose Xylose Peptone	White	Cottony	Sparse
			"	"	"
			"	"	None
16	White	Milk Dextrose Xylose Peptone	"	"	Sparse
			"	"	None
			"	"	"
			"	"	"

#### MEASUREMENTS OF SPORES OF NIGROSPORA FROM HOSTS OTHER THAN MAIZE

Mason (6) placed small-spored *Nigrospora* strains in the species *N. oryzae* (B. and Br.) Petch. As the name indicates, this species occurred on rice. It is of interest to note that of the four rice specimens examined by Mason, one had spores with an average diameter of  $18\mu$ , which is larger than the spores of *N. oryzae* as he defined it.

Rice leaves<sup>3</sup> infected with *Nigrospora* were examined during the course of the present investigation. Spore diameters were found to be extremely variable. Measurements of 30 spores from each of five leaves gave average diameters of  $15.2$ ,  $15.2$ ,  $15.3$ ,  $15.5$ , and  $15.7\mu$ . The extremes in spore diameters observed were  $11.7$  and  $21.4\mu$ . The average spore diameter for each of these specimens was greater than that characteristic of *N. oryzae* and less than that of *N. sphaerica* and thus could not properly be assigned to either of these two species on the basis of Mason's separation.

<sup>3</sup> Obtained from Dr. T. C. Ryker, Agricultural Experiment Station, University of Louisiana.

In a limited study of variability of isolates from hosts other than maize, *Nigrospora* cultures from several parts of the world, including isolates from wheat, rice, sugar cane, and banana, were compared with those obtained from maize. Data on eleven of these isolates and on four isolates from maize are presented in Table 6. The characteristics of the isolates showed wide variability, even in isolates from the hosts (e.g., banana and maize). Mycelial color varied from white to black, and growth ranged from low and sparse to cottony and tufted. Sporulation varied from none to abundant. The variability of the fungus from all these hosts apparently was no greater than that on maize.

#### SPECIES OF NIGROSPORA ON MAIZE

Mason (6) held that "three species may provisionally be accepted," *N. oryzae* (B. and Br.) Petch, *N. sphaerica* (Sacc.) Mason, and *N. sacchari* (Speg.) Mason, characterized by spore size. Mason found two of these species on maize, namely *N. oryzae*, with spores averaging 13.5 to 15.0 $\mu$  and *N. sphaerica*, 16.5 to 18.0 $\mu$ . The data set forth in the present paper indicated the *Nigrospora* as it occurred on maize was exceedingly variable not only in spore size but also in other characteristics.

Average spore measurements on field collections over the four-year period, 1938 to 1941, ranged from 9.0 to 17.8 $\mu$ <sup>4</sup>. Many of the measurements fell outside Mason's two species on the basis of spore size. In 1940 and 1941 the average diameters showed a bimodal distribution similar to but less pronounced than that on which Mason separated two species. The narrow margin of separation between species on the basis of spore size and the large number of collections with average spore diameters intermediate in size indicated that this bimodal distribution had little or no significance. The size of spores in field collections failed to show any relationship to symptoms in the infected tissues.

Isolates of the fungus varied in culture. The color of the mycelium ranged from white to nearly black. In some isolates the mycelium was compact, in others cottony and tufted. Time of sporulations ranged from 2 to 21 days or more. Sporulation was profuse in some isolates and not observed in others. There was no uniform relationship between spore size and cultural characteristics, although isolates from large-spored collections were in general more variable than those from small-spored collections. Single-spore isolates from large-spored collections produced uniformly small spores in culture.

In the light of the variability in spore size and cultural characteristics of the *Nigrospora* collected on maize, it was necessary to choose either *N. oryzae* or *N. sphaerica* as the specific name of *Nigrospora* on maize in Iowa. The choice, however, apparently was predetermined by virtue of earlier work.

In 1875 Berkeley and Broome (1) described *Monotospora oryzae* on

<sup>4</sup>Dr. B. Koehler, Ill. Agr. Exp. Sta., in correspondences with the author, expressed some doubt that two species exist on maize. This doubt was based on some preliminary spore measurements and observations of cultural characteristics.

TABLE 6  
SPORE MEASUREMENTS AND COLOR OF MYCELIUM IN CULTURE OF ELEVEN NIGROSPORA ISOLATES  
FROM HOSTS OTHER THAN MAIZE, AND OF FOUR ISOLATES FROM MAIZE

Isolate	Immediate Source	Host	Locality	Spore Diameters in Microns		Color Mycelium on Potato-Dextrose Agar
				30 Spores Average	Range	
<i>N. spharica</i> (Sacc.) Mason	C.B.S.*	Banana	West Indies	16.8	10.0-19.9	Very light gray
<i>N. oryzae</i> (B. & Br.) Petch	C.B.S.	Sugar cane	Mauritius	14.5	13.5-16.4	Gray
<i>N. oryzae</i>	Mason†	Wheat (culms)	Saskatchewan	14.2	12.5-15.7	Gray
<i>N. oryzae</i>	Ryker‡	Rice	Louisiana	13.5	10.7-15.3	Gray
<i>N. Panici</i> Kuiper (not Zimmermann)		Not stated	Not stated	18.8	16.0-21.4	Tan-gray
<i>N. sp.</i>	C.B.S.	Banana (leaf)	Australia §	14.2	14.7-14.6	Gray
<i>N. musae</i> (McL. & H.)	Standen	Banana (fruit)	"	17.2¶	13.5-22.4	White
<i>N. canescens</i> (McL. & H.)	McLennan §	Banana (leaf)	"	17.2	16.0-17	Dark gray
<i>N. sp.</i>	Simmonds	"	"	20.5	14.2-26.7	Gray
<i>N. sp.</i>	"	"	"	12.1	10.7-13.5	Dark gray
<i>N. oryzae</i> **	Standen	Corn, 1937	Iowa	14.2	13.2-15.3	Gray
<i>N. oryzae</i>	"	Corn, 1936	"	15.5	11.7-20.3	White
<i>N. oryzae</i>	"	"	"	15.1	13.9-17.1	White
<i>N. sp.</i>	Hoppe††	Corn, 1939	Wisconsin	21.7	20.6-23.8	Black

\* Centraalbureau voor Schimmelcultures, Boorn, Holland.

† E. W. Mason, Imp. Mycol. Inst., New England. This culture was received from R. C. Russell, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

‡ T. C. Ryker, Agricultural Experiment Station, University of Louisiana.

§ (Miss) E. I. McLennan, University of Melbourne, Melbourne, Australia.

|| Submitted by J. H. Simmonds, Dept. Agr. and Stock, Brisbane, Australia. These three isolates were designated by number only (5431, 4531, 5402).

¶ McLennan and Hoette (7) give 18.0 $\mu$  as the average for *N. musae*, and 19.0 $\mu$  for *N. canescens*.

\*\* Cultures No. a-2, 12, and Gr. 16, J. H. Standen.

†† P. E. Hoppe, U.S.D.A., Bur. Plant Ind., Madison, Wisconsin.

rice leaves from Ceylon with spore diameters from 13.5 to 15.0 $\mu$ . Mason (6) examined a type specimen in the Kew Herbarium and confirmed Petch (10) who in 1924 transferred the fungus to Zimmermann's genus *Nigrospora* (14) as *N. oryzae* (B. and Br.) Petch. According to Mason this was the oldest collection of the fungus of which type material was available. In addition, this species name was the oldest that could with certainty be applied to the fungus. Mason placed all small-spored collections in *N. oryzae*. Mason (6) recognized also a second species of *Nigrospora* having larger spores than *N. oryzae*, averaging 16.5 to 18 $\mu$ . This he named *N. sphaerica* (Sacc.) Mason, which was based on a fungus collected by Ellis on maize culms in New Jersey in 1882 and named *Trichosporium sphaericum* by Saccardo (12).

It has been shown that collections with large spores tend to produce small spores in culture, and so it becomes difficult to differentiate a large-spored species. Accordingly, the Iowa collections are all referred to as *Nigrospora oryzae*.

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## CORRECTION

In my paper entitled, "New Tingitidae (Hemiptera)" in the October, 1942, issue of this Journal, the specific name *solida* is used for two different species of the genus *Amblystira*, pp. 16 and 17. This is due to a typesetting error and not noticed until the Journal was distributed. The name *Amblystira amica*, n. sp. is here published for the name *Amblystira solida* on page 17 for the type specimen from Hinche, Haiti.—C. J. Drake

A BOTANICAL SURVEY IN THE IOWA LAKE REGION OF CLAY  
AND PALO ALTO COUNTIES<sup>1</sup>

ADA HAYDEN

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Received June, 1942

## REASONS FOR THE PLANT SURVEY

A survey of the plants useful to waterfowl was undertaken in the vicinity of Ruthven, Iowa, as a part of a cooperative research program which had been initiated in the state-owned wildlife areas and preserves located in the lake region of Clay and Palo Alto Counties. The state preserves include chiefly the less arable lands of the two counties which lie in the upper half of the Wisconsin Drift Lake Region and comprise about 1 per cent of the 713,360 acres covered by the two counties. Based upon a knowledge of the plants of the region useful to waterfowl, many wildlife investigations have been carried on including those of Errington and Bennett (1933), and Errington (1937), Errington and Hamerstrom (1937), Friley, Bennett and Hendrickson (1938), Scott and Selko (1939), Scott (1940), Sooter (1937), Low (1939 and 1940), and Spawn (1935).

Bennett (1938) prepared a map, in which he referred to a tract nine sections wide by thirteen sections long in the vicinity of Ruthven as the Ruthven area (Fig. 1). This locality, because of the favorable conditions afforded by its lakes, swamps, and sloughs, is a center of occupation by local waterfowl during the nesting period and by migratory waterfowl in season. The diversity of environment in and about the waterways and meadows of the Ruthven area affords favorable habitats for native plants upon which waterfowl are dependent for cover, food, and building materials. Not only is it essential to know the identity, abundance, and distribution of plants used by waterfowl in their local breeding grounds, which vary in aspects of physiography, drainage, and biotic factors, but inquiry should also be made concerning the ranges of both plants and waterfowl, for regional flora and fauna are limited in their distribution by geographic and climatic phenomena. Such considerations should be useful in recognizing the basis of plant distribution for a region, and should afford perspective in the field of wildlife management where discrimination must be exercised in the introduction of suitable service plants in the artificial wildlife preserve.

This paper reports a summary of observations made during seven growing seasons beginning in April, 1934. The list of plants and the photographs of plant communities are the original contribution of the

<sup>1</sup> Journal Paper No. J-1046 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 366.

<sup>2</sup> The Fish and Wildlife Service (U.S. Department of the Interior), Iowa State College, Iowa State Conservation Commission and the American Wildlife Institute Cooperating.

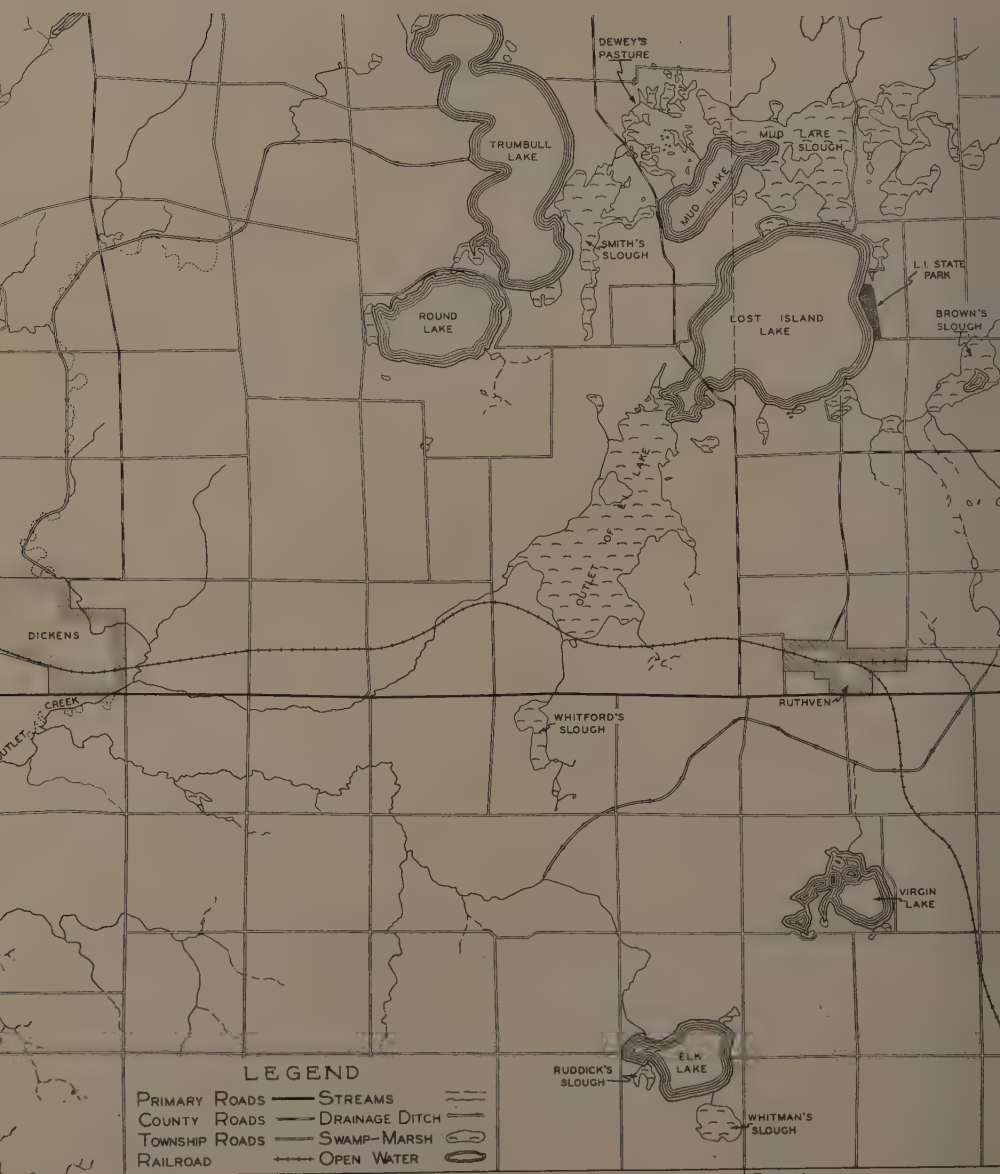


FIG. 1. A MAP OF THE RUTHVEN AREA.

*Preparation.* The map was drawn by the Drafting Service of the Agricultural Engineering Department of Iowa State College according to the specifications made by the writer. It was based upon a composite map constructed by assembling the  $9 \times 9$  inch contact prints from aerial negatives made by the U.S.D.A. Agricultural Adjustment Administration in 1939. The photographic maps were mounted upon a masonite foundation to form a composite map including a portion of Clay and Palo Alto Counties  $8 \times 13$  sections in size. From this photographic map a tracing was made and a map drafted. The names of the physical features were designated after consulting the geological maps of Macbride (1901 and 1905), the soil maps of Clay and Palo Alto Counties by Stevenson and Brown (1919 and 1922), the maps of the Iowa Lake and Lake Bed Survey prepared by the Iowa State Highway Commission (1917), the State Highway and Transportation map (1940), and the map of the Ruthven Area by Logan Bennett (1938). The physical features which are practically obliterated by drainage or other causes are not shown on this map, for example, Rossacker's Slough and Elbow Lake. The relative position of the main lakes with their sloughs and drainage systems are shown. The term slough may be regarded as a popular term for a swamp, marsh, or fen elsewhere defined. This group of lakes drains theoretically to the westward through the three branches of Outlet Creek, which flows in a south-westerly direction into the Little Sioux River. One feature of importance is the modification of the natural drainage channels shown in the geological maps of 1901 and 1905. The roads are designated, but the township lines are only suggested as defined by the roads.

writer. However, a list of plants is useful only as it can be applied to related subjects, and therefore, the list is preceded by a discussion referring to the significance of the plants as constituents of vegetation, as members of floras, as physiographic units, and as materials useful to man in the art of living, as well as in the pursuits of agriculture.

#### LOCATION OF THE UNIT STUDIED

The territory defined by the political boundaries of Clay and Palo Alto Counties was arbitrarily delineated though it constitutes a related part of a topographic unit, because this area includes two of the four counties lying directly in the Wisconsin Drift Lake District. Between the two counties lies a divide in the drainage system known in its north-westerly extension into Minnesota and the Dakotas as the Coteau des Prairies (Calvin 1925 and map of Nicollet 1845). Palo Alto is drained by the West Fork of the Des Moines River with its tributaries and Clay by the Little Sioux with its tributaries. Clay, like Dickinson County adjacent on the north, is mantled both by Early Wisconsin (Iowan) and Late Wisconsin Drift (Mankato) (Fig. 2). Palo Alto, like Emmet on the north, is covered by a glacial deposit of Late Wisconsin, and the two counties through their central north-south axis are dotted by a group of walled lakes, potholes, sloughs, and swamps which constitute one drainage unit of the Wisconsin Drift District (Fig. 1). The geographic center of this unit is defined approximately by the intersection of the forty-third meridian north and the ninety-fifth west.

#### PREVIOUS STUDIES OF THE NATURAL VEGETATION OF THE WISCONSIN DRIFT LAKE REGION

Accurate comparisons of the vegetation of the surrounding counties cannot be made on a basis of previous data, since few intensive studies have been made for this region. Not many specimens from Clay and Palo Alto Counties occurred in the herbarium of Iowa State College before the present survey was begun. Most of these were collected by L. H. Pammel. About 100 sheets consisting chiefly of grasses, sedges, and legumes were contributed to the Iowa State College Herbarium by Jess Fults while conducting a soil survey in Iowa. In 1934 a gift of fifty plants from a more extensive collection was received from Frances and Frederick Hamerstrom while they were studying the environment of the Ring-necked Pheasant in the Ruthven Area. Sheets in the herbarium of the University of Iowa, also representing Clay and Palo Alto Counties, are few. The collections reported in the annotated list of this paper include about 3,000 specimens which are filed in the Herbarium of Iowa State College, duplicates of which have been sent to the larger herbaria of the United States.

Comprehensive studies of the flora of Emmet County have been made by R. I. Cratty (1882, 1904, and 1905) and B. O. Wolden (1932) over a period of forty years. Aquatic seed plants, as well as the upland flora, are represented. The personal collection of Mr. Cratty, upon which his papers

are based, is a part of the herbarium of Iowa State College, and duplicates of the extensive collection of Mr. Wolden are also filed there. Conard and Wolden (1932) published a key to the Mosses of the Okoboji region.

Bohumil Shimek collected intensively in Lyon and Dickinson Counties in this region and reported many of his collections in a series of papers dealing with the prairie (1897, 1911, 1915, and 1925). Through a period of years the flora of the Lake Okoboji region has been collected, deposited in the Herbarium of the University of Iowa, and reported in papers by students and staff of the Lakeside Laboratory of the University of Iowa at Miller's Bay, Lake Okoboji. A comprehensive study of the Algae of Dickinson County has been made by Prescott (1931) and Tiffany (1926), and the major aquatic plants of Lake Okoboji have been reported by Wylie (1920).

## THE PHYSICAL ENVIRONMENT OF THE VEGETATION

### VEGETATION AND CLIMATE

The vegetative areas of a region are the product of its past and present edaphic and climatic factors. These will be discussed so far as they apply to the present problem. However, the selection of some descriptive term for the vegetative areas must be made from the many which have been used by investigators in this field.

It is obvious that in the successive efforts to establish the boundaries of natural vegetative areas for the United States or for the continent, many contributing influences have been evaluated. Meyen (1836) divided the horizontal range of vegetation into world-encircling zones determined more or less by the temperature of the air. Grisebach (1872) recognized the twenty-four separate centers of development, one of which was the prairie region. Drude (1890) referred to the Missouri-prairie region in North America. Merriam (1898) described life zones which he referred to as boreal, austral, and tropical, which were designated by the plants and animals native there. These were based upon the summation of heat for the growing season and the average temperature of the six hottest months by which isothermal lines were derived. Clements (1902) referred to a prairie region, Engler (1902) designated a prairie province of Atlantic North America with three divisions, the northern, a middle, and a southern zone. Harshberger (1911) evolved a phytogeographic map of North America based upon the foregoing in which northern Iowa was described with the prairie-great plains region. Shreve (1917) mapped the vegetation of the United States on the basis of natural assemblages of plants which he described in eighteen areas. Northwestern Iowa was represented as a lobe of the grassland jutting into the forest-transition zone.

The map of Livingston and Shreve (1921) was based upon the precipitation-evaporation ratio (P/E) for the average frostless season. This ratio was introduced by Transeau in 1905. In this map the whole of the Iowa area was referred to the grassland-deciduous forest transition. Shantz and Zon (1924) prepared a map of natural vegetation represented



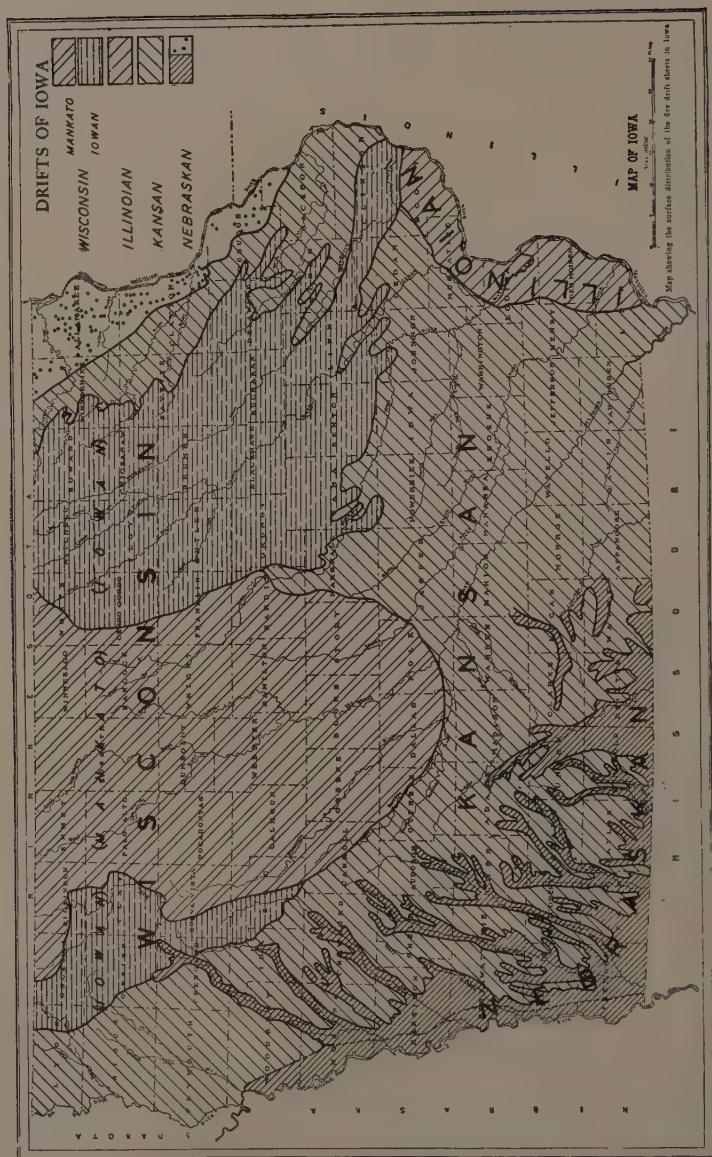


FIG. 2. Map of glacial drift sheets of Iowa. (From G. F. Kay and Paul T. Miller in the Pleistocene Gravels of Iowa. By courtesy of the Iowa Geological Survey.)

only by distribution of native plants to which they refer as the biological unit. In the map of Shantz and Zon, the short-grass prairie was distinguished from the tall-grass prairie which appears to be regarded as a forest transition. Iowa is referred to the tall-grass prairie.

Thornthwaite proposed (1931) a new set of climatic provinces for North America emphasizing that, since climatic influences must have determined soil formation, each climatic province should have its own climax vegetation type. He pointed out that his climatic provinces are consequently soil provinces as well. In Van Dersal's *Treatise on Native Woody Plants of the United States* (1938), there appears a map of plant-growth regions prepared by Mulford, which was based upon climatic and soil factors, and designated zones or areas having fairly uniform growing conditions. The correlation of Mulford's plant-growth regions with natural vegetation areas has not yet appeared in print. In the characterization of the conditions in the growth regions, three main items were included for each: the climate, expressed in terms of Thornthwaite's climatic provinces, the length of the growing season, and the average annual number of days with snow cover.

In this development of the concept of vegetation areas of North America, the term prairie has persisted, whatever other descriptive names may be applied to Iowa. Prairie it was to the native layman, who first looked upon its grassy cover, and prairie it is to the scientifically trained person, who judges the area, now nearly stripped of native cover, by its climate and soil. Northern prairie is distinguished by its vegetative constituents and soil types from the climatically differing southern prairie. But various characteristics separate Iowa also into sections which differ climatically, edaphically, and vegetatively.

#### THE CLIMATE OF NORTHWESTERN IOWA

Climate is essentially concerned with temperature, moisture, and air movements resulting from changes in temperature expressed in some degree by a summary of factors pertaining to water and heat. The interaction of moisture and temperature working together may be expressed as humidity, evaporation, or precipitation. Thornthwaite stated that since climatic influences must have determined soil formation, each climatic province should have its own climax vegetation type. His climatic provinces as applied to this area will be further discussed following the climatological data of the Weather Bureau for northwestern Iowa.

The climate of Clay and Palo Alto Counties is essentially that of the northwestern district of Iowa. The direction of the prevailing winds is from the northwest, but during the period from the middle of May to the middle of September it is from the south to southeast. The aspect of much of Iowa has changed from a treeless prairie to a covering of groves and shelter-belt trees, averaging possibly 50 feet or more in height, which undoubtedly has greatly decreased locally the general wind movement at the surface of the ground, and this probably accounts largely for the popular impression that the climate is growing milder. Wind velocity is

in general highest in the northwestern section of the state, and evaporation is proportionately high. The winters are long and often severe; temperature minima of  $-20^{\circ}$  to  $-36^{\circ}\text{F}$ . have been recorded. During July, extremes of  $100^{\circ}$  and  $104^{\circ}\text{F}$ . have been recorded by the weather stations of these counties. The following climatological data is taken from the U. S. Weather Report, Iowa Section (1939, pp. 95-100). It is based on estimates for a thirty-five-year period.

The normal annual precipitation in Clay and Palo Alto Counties is 28-30 inches. The state average is 31.56 inches. The January normal precipitation averages .75 inches for the northwestern section. The average for the state is 1.09 inches. January is Iowa's driest month. Normal precipitation in June for the northwestern section is 4.5 to 5.0 inches. The state average is 4.62 inches. Snowfall averages 29.9 inches per year for Iowa, reaching as much as 45.9 inches in the north.

The normal annual temperature for the Clay and Palo Alto sections is  $45^{\circ}\text{F}$ . The state average is  $48^{\circ}\text{F}$ . In the northwestern section, January is the coldest month, and its average normal temperature is  $13-14^{\circ}\text{F}$ . The state average is  $18.6^{\circ}\text{F}$ . For July, the hottest month, the average temperature of the Clay and Palo Alto district is  $73^{\circ}\text{F}$ . The state average is  $74.6^{\circ}\text{F}$ . Only four years in sixty-seven (since 1873) had a higher average temperature than 1939, which averaged  $51.1^{\circ}\text{F}$ ., or  $3.1^{\circ}\text{F}$ . above the sixty-seven-year average.

The length of the growing season based on forty years of data is 150 days for the Clay and Palo Alto district; the average for the state is 158 days. The average date of the last killing frost or freeze in spring is May 10, and the average date of the first killing frost in fall is October 5.

It is generally recognized that the degree of temperature, the amount of precipitation, and seasonal variations of each are the most important climatic elements. A proposed index of precipitation effectiveness was originated by Transeau in 1905 by using the quotient of total annual measured precipitation and annual evaporation ( $P/E$ ). This principle was modified by Thornthwaite (1931) who devised the method whereby the precipitation-evaporation quotient ( $P/E$ ) can be computed, where only the mean monthly temperature and monthly precipitation are given. An inspection of the foregoing data from the Iowa Weather Bureau indicates that northwestern Iowa has a grassland climate since the greater part of the yearly precipitation occurs in the summer months and the evaporation ( $P/E$ ) is low. The map of Iowa showing the original forest cover in relation to grass cover (Fig. 3) illustrates the predominance of grassland in northwestern Iowa.

The maps of Thornthwaite (1931) and Mulford (in VanDersal, 1938) describe the climate and plant growth regions for Iowa more exactly than earlier maps. Thornthwaite's climatic provinces (1931) are based upon the factors of humidity, temperature, and seasonal distribution of precipitation. The combination of these three constitute the factor basis for forming a climatic province. The five major humidity provinces are described as A (wet), B (humid), C (subhumid), D (semiarid), and E (arid). Four

# IOWA STATE PLAN

# ORIGINAL FOREST COVER



BASED ON DATA SECURED  
IN THE ORIGINAL LAND  
SURVEY MADE IN  
MICHIGAN, WISCONSIN  
AND IOWA TERRITORIES  
WHEN ALL BASIC POINTS  
SECTIONAL LINES AND  
TOWNSHIP LINES WERE  
ESTABLISHED.

SURVEY STARTED -  
MARCH 23, 1852  
SURVEY COMPLETED -  
AUGUST 17, 1859

WISCONSIN  
ILLINOIS



IOWA  
STATE PLANNING  
BOARD

THE COMMITTEE ON  
FOREST AND  
WATTLAND  
PROJECT  
1033

LEGEND

FOREST





subtypes were recognized as limited by the moisture available in different seasons. The limiting effect of temperature on plants was expressed in the same manner. The data with which he derived the indices and ratios by which the provinces are determined were secured by field observation, vegetative maps, and monographs. The length of the growing season and snow cover were taken from the *Atlas of American Agriculture*.

An unpublished map constructed by H. O. Perkins under the direction of Dr. J. M. Aikman in 1940 was based upon P/E ratios, length of growing season, temperature, and soil areas. It divides the climate of Iowa into seven sections, further differentiating the territory which the climatic map of Thornthwaite designates as only one; and which the plant growth map of Mulford divides into three sections. The distribution of native plants of Iowa, particularly those which have indicator values, warrant further inquiry into the delineation of climatic sections of the state.

As mapped by Thornthwaite (1931), northwestern Iowa lies in the province classified as to humidity, subhumid; as to temperature, microthermal; and as to seasonal distribution of precipitation, adequate at all times. It lies in the northern prairie, according to the plant growth regions described by Mulford, in the map published by Van Dersal (1938).

#### GEOLOGY OF CLAY AND PALO ALTO COUNTIES

Only brief references will be made to the glacial history, soils, and physiography of this region, which are comprehensively treated by Macbride (1901 and 1905), White (1870), Kay and Apfel (1929), Kay and Leighton (1933), Brown, (1936), Walker and Brown (1936), Stevenson (1919 and 1922), and others.

#### GLACIAL HISTORY

Though the territory of Clay and Palo Alto Counties lies within the northwestern third of Iowa once washed by Cretaceous seas, the Cretaceous (Dakota) sandstone lies deeply buried beneath glacial deposits, so that its presence is indicated only by the identification of materials secured from well borings. There are no exposures of rock any place in either of the counties. Four times glaciers have advanced from a northerly direction across this territory during the Pleistocene Age. The drift of the earliest Nebraska glacier appears to have been obliterated by erosion processes before the time of subsequent deposits. Records show that deposits of the Kansan glacier vary in depth from 30-60 feet in Clay County and from 1-300 feet in Palo Alto County, depending on the extent of pre-Wisconsin erosion. It consists mainly of blue clay, somewhat sandy or mixed with gravel. Small boulders are commonly present. Beneath this drift are the pre-Kansan sands. These lower layers of the Kansan deposit are the source of the supply of well-water for the region.

From the deposits of the latest or Wisconsin glacier are derived the

rich soils which support the vegetation of the area. The surface of the Iowan or Early Wisconsin constitutes the western three-fourths of the surface of Clay County. It is a thin drift with a gently rolling mantled erosional topography. Some thousands of years later, the Wisconsin advanced as a second lobe, known as the Mankato, or Late Wisconsin. The drift, a mixture of boulders, gravel, silt, and clay, left by the retreating glacier varies in depth from a few inches to 150 feet in thickness. The greatest depth is reached in the terminal moraine (Altamont), which runs in a north and south direction through the western half of Palo Alto County and extends along the eastern border of Clay County. So recently did the Late Wisconsin melt away that the streams in this region are still shallow and meandering, with ill-defined courses and loosely packed banks. In the vicinity of the moraine are many shallow drift lakes, kettle-hole ponds, and marshes. Following the retreat of the Early and the Late Wisconsin, the chemical weathering of the drift into gumbotil and related materials did not follow, but a widespread black soil was formed.

## THE SOILS

### *Drift, Terrace, Swamp and Bottomland*

According to Stevenson and Brown (1919 and 1922), the soils are grouped in three classes according to their origin and location. These classes are drift soils, terrace soils, swamp and bottomland soils.

Drift soils are those which are formed from the material deposited by the glacier on its retreat, and they contain rock materials from various sources, sometimes pebbles and boulders. They cover about three-fourths of the area of each county. In Clay County the drift soils include six types of the Carrington series, one of Webster, and one of Shelby. The Carrington loam is the most important soil type in the county. Including the steep phase, it covers 31.3 per cent of the total area. In Palo Alto County the drift soils include three types of the Webster series, four types of Clarion, and one type of the Rogers. The Clarion loam is the largest individual type of the county, including 37.7 per cent of the area.

Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which formed them, or a deepening of the river channels. The terrace soils of Clay County include two types of the O'Neill series, one of Fargo, and one of Wausheka. The O'Neill loam, which is the most important terrace type, covers 8.1 per cent of the county. In Palo Alto County the terrace soils include two types of the O'Neill series, which are both minor in extent.

The swamp and bottomland soils are those which occur in low, poorly drained areas or those found along streams and subject to varying degrees of overflow. In Clay County there are two types of the Lamoure series, one of the Wabash, and the remainder consists of muck and peat. The Lamoure silty clay loam is the most important bottomland soil, constituting 11.9 per cent of the county. This class of soils in Palo Alto County includes one type of the Lamoure series, one of the Wabash, two of the



Cass, and the remainder is peat and muck. The Lamoure silty clay loam is the most widely represented, covering 14.4 per cent of the whole area.

## PHYSIOGRAPHY

### *Topography*

Clay and Palo Alto Counties were originally a part of the uncharted northwest prairie, which includes the most elevated portion of the state; and yet its highest point of elevation (1,680 feet near Sibley) is only about 1,700 feet above the level of the sea and only between 1,200 and 1,300 feet above the lowest point (444 feet) in the state. The highest altitudes of Clay and Palo Alto Counties range around 1,400 feet (Table 1). The difference in levels is scarcely perceptible to the eye; for much of the surface is gently undulatory, knobby in the vicinity of moraines, and occasionally cut by a shallow valley. So slight are the variations in elevation, and so little is the view obstructed by trees, that the general impression is that of a plain. The morainic hills, which in Dickinson County are so conspicuous a feature, terminate rather abruptly at the southern boundary of the county, where a high but marshy plain continues southward into Clay County for several miles, and is drained to the westward by Meadow Brook. To the east, the marshes deepen into lakes. The characteristic morainal topography gradually reappears, and the whole eastern side of Clay County is covered with typical knobby drift, sometimes showing disconnected hills and ridges 150 to 200 feet above the stream valleys. Such topography is illustrated in Freeman and Logan Townships and is continuous into Palo Alto County, where Ruthven stands high on morainic hills at an elevation of 1,413 feet. Toward the southeast, the hills grow lower, though the general level is still high. At Gillett's Grove, where the hills meet the Little Sioux River, they deflect it almost directly westward, where it courses through great beds of typical Wisconsin drift.

Macbride (1901) recognized two types of valleys, the constructional and the erosional. The constructional valley may have any form or contour such as mere depressions, beds of lakes, imperfectly drained lakes largely filled, or tortuous streams. The erosional valley has the form of a ditch—a drainage channel shaped by descending waters. In the morainic part of the territory the valleys of construction are basin-like and form the beds of marshes or lakes. This type is illustrated in the eastern part of Clay County by such lakes as Round (Swan), Trumbull, Lost Island, Elk, and Mud (Pelican) (Fig. 1). These lakes now are more or less connected in periods of high water, but as they existed in natural state, they constituted natural reservoirs; though they were, also, a part of the sluggish drainage system. Erosive processes contribute only to their diminished depth. They are characteristic of morainal topography. Series of unnamed marshes and swamps form numerous other constructional valleys of lesser extent.

A notable constructional valley of interest may be seen as one proceeds south from Elk Lake. There a large valley comes in view extending

east and west, in a broad curve of wide expanse across the township. The depression lies 100 to 120 feet below the general level. No stream is visible, but a marsh is found with no perceptible current. In other places a small rivulet may be discovered winding back and forth across the level bottom land. Other small streams ramify with it, and the valley narrows as its mouth is approached until it joins the valley of the Little Sioux, where it becomes an erosional channel hemmed in on both sides by precipitous hills. This valley, with the little stream that wanders through it, is called Elk Creek. Its general course is westward, and it receives the overflow of Elk Lake by the way of fens and marshes lying in Palo Alto County, far east of the point of origin. In 1901 Macbride wrote, "The sides of the valley, the banks, for such they really are, are broken by short, little, narrow gutters and secondary ravines seaming the grassy sides, affording the general impression of very recent erosion. In fact, everything indicates that rapid erosion is going on now. The land is shaping itself almost before our eyes. Give us a little time and these abutting banks will lose their minatory character; long gentle slopes will take the place of bluffs now so steep and forbidding; even the table-land will vanish and long, low valleys will lead waters down to the then persistent channel of Elk Creek." Such constructional valleys, characteristic of a morainal province, occur throughout this region. The hills are not continuous but occur in groups, marking, it seems, the local halts and recessions of the disappearing ice. However, three distinct types of topography are discernable; the groups of hills, the high plains between the streams, and the level plains which lie in some places by the streams.

The eastern half of Palo Alto County is covered by a broad to rolling undulating plain, whose surface bearing scattered knobs is not materially changed by erosion. Though the country appears comparatively level to the eye, it slopes gently to the south. In the western part of the county a series of high morainal hills may be seen west of the Des Moines River. Chains of lesser height extend northeast of Emmetsburg, Rodman, and West Bend. Lying among the morainal hills are lakes of various dimensions including Lost Island, Mud (Pelican), Medium, Silver, Rush, and a lake formerly known as Elbow, which is now drained. Adjoining the lakes which have well-defined banks are long, low swamps. No streams run among the high morainal hills around Ruthven or Graettinger. (Table 1, p. 25.) Sometimes the hills are grouped together like miniature mountains a hundred feet high.

The river valley proper shows a plain topography of a different character from that of the undulating drift plains to the northeast. Alternating on either side of the river is a gravel plain which lies below the level of the general plain, and distinct in structure and position. It reaches the hills where they are present and varies from one to three miles in width. It is composed of water-laid sand, boulders, and gravel 15 or 20 feet in depth, often resting on blue clay. The waters of the present Des Moines River never reach this plain, which is the bed of a post-glacial river. On its bed are located Graettinger, Wallingford, Osgood, a part of Emmets-

burg, and Cylinder. This sandy, gravelly plain extends as far as four miles north of Cylinder and is three or four miles in width. Its extent may be seen from the hill west of the Osgood bridge over the river.

Reaching across the adjoining surfaces of the Clay and Palo Alto territory, a post-glacial lake leaves traces of its history. It is bounded by the limits of a wide sand plain. Macbride describes the bed of this lake whose low shores may be followed from the territory north of Spencer east and south, including perhaps all of Lost Island Lake and the adjacent waterways. This post-glacial body of water known as Lake Spencer must have received all the drainage from the melting ice in this part of Iowa including the areas occupied by the Ocheyedan and the Little Sioux. Lost Island Lake was out of the course of drainage and remained deep. The deposition seems to have gone on steadily, until the gravel had filled up not only Spencer Lake from east of Dickens almost to Everly, but had choked up all main streams to the north. Eventually erosion worked northward from a pre-Wisconsin channel south of Cherokee and eastward by a constructional valley along the present valley of the Little Sioux until it cut through at Peterson, forming rapids there and draining the marsh in the vicinity of Lynn Grove. At length, erosion channels cut through the divide of Wisconsin clay that limited Lake Spencer at Gillett Grove, and this post-glacial lake was drained. The bridge in Spencer crosses this channel and floodplain.

#### *Drainage*

The story of drainage in the territory of Clay and Palo Alto Counties is largely concerned with the courses of two rivers and their tributaries, the Little Sioux and the Des Moines. Their water courses drain the area of more or less undulating drift separated by the elevation of the Altamont Moraine, which covers the western half of Palo Alto County and reaches into the eastern border of Clay County. This high land constitutes the divide which diverts the run-off from Palo Alto County into the Mississippi and the run-off from Clay County into the Missouri River. Though many more ponds and swamps still exist in this part of the state than elsewhere, the acceleration of run-off by the use of tile and dredge ditches has somewhat modified the natural drainage. This with the removal of the natural vegetative covering has changed the water of the clear streams and lakes to a turbid condition.

Though points on the open prairie north and south in Clay County show the same elevation, the general slope of the country is toward the south. The streams of the region flow south, southeast, or ultimately southwest. Clay County is comparatively well drained by the Little Sioux River, whose windings cause it to travel over a large part of the county. Its tributaries have sluggish currents winding from slough to slough. As the Little Sioux enters Clay County near the northeast corner of Summit Township, it passes through a broad valley which winds through a sandy plain, where it is joined by the Ocheyedan. The waters of the two streams flow eastward, where they are deflected to the west

by the hills of the Altamont Moraine at the east side of the county. Here the stream passes out of Sioux Township into an erosion valley, which becomes narrow and tortuous as the stream bed cuts through high banks of drift at Gillett Grove and winds southwestward around a lobe of the moraine. After five or six miles, it receives the waters of Willow Creek and cuts circuitously through the drift out of the county and back up through the corner of Peterson Township at Peterson. From the general upland level down to the water in the stream at Peterson, the depth is 190 feet. Upon the steep valley sides no exposure of rock is to be seen—only the drift, with its occasional boulders.

In Palo Alto County the valley of the west fork of the Des Moines River constitutes the principal drainage channel first formed and excavated by glacial drainage and later partially filled. By the high morainal hills of western Palo Alto County, the river is diverted to the east until just south of Emmetsburg, low morainic ridges change its course eastward, where it meets south of Rodman, the West Bend series of hills, through which the stream winds its way out of the county. "The pre-Wisconsin drainage," stated Macbride (1905), "was not very different in direction, at least, from that which obtains today. Great ridges of older drift are still in evidence, which for ages have been watersheds. The Wisconsin simply threw these forceful streams into confusion. The uncertain course of the Des Moines across these prairies is apparent when one notes the often slight character of the obstacle by which the stream has been deflected."\*

## OCCUPATION OF THE REGION BY MAN: BIOTIC INFLUENCES

### EARLY SETTLEMENTS

The territory of Iowa was the early abode of the Sac, Iowa, Dakota, and Fox tribes of Indians, who refused to permit white men to settle. The conclusion of the Black Hawk war in 1832 resulted in the cession of thousands of square miles in eastern Iowa, and during the next few years the whole of Iowa territory was secured from the Indians by treaties. Permission to settle in Iowa was first granted to the white man in June, 1833. The census in May, 1838, showed that the population was 22,859. The Act of Congress of 1838 divided the territory of Wisconsin and established the territorial government of Iowa by constitution. Until the formation of the State in 1846, this constitution was its fundamental law. In 1847, Iowa included thirty counties in the southeast section, and the remainder of the state was unsurveyed. As settlement moved westward and the hostile Indians became more difficult to control, a fort was established at Fort Clarke in 1849, later known as Fort Dodge. McCarty (1910), in the History of Palo Alto County, states at this time no permanent settler had entered Palo Alto County. However, as the United States troops, on their removal from Fort Dodge in 1854, marched to Fort Ridgely, their course took them along the river. One evening they came to a beautiful little lake and made their camp in an oak grove upon the shore. This lake is

now called Medium Lake. There they remained in Palo Alto County for several days on account of a severe storm. Lieutenant Albert M. Lea, of the U. S. Dragoons, in his travels and exploration of Iowa (1836) wrote: "The Des Moines River and its tributaries afford fine lands, well diversified with wood and prairie, as far up as I am acquainted with them, some fifty miles above the 'Upper Forks.' There is much that is inviting in the general character of the country bordering on the Des Moines; level meadows, rolling woodlands, and deep forests, present themselves by turns. The soil is usually rich and productive; and when there are no natural springs there is no difficulty in obtaining water, by digging, at almost any point in the highland-prairies."

The first settlement was made in Palo Alto in May, 1855, by the families of William Carter and Jeremiah Evans. They came from Benton County by ox team and from Fort Dodge followed the dim trail to the northwest, known as the "Military Road," where supply wagons of the soldiers going to Fort Ridgely had left their marks in the prairie grass. These families went as far north along the east border of Medium Lake as Jackman's Grove but decided to retrace their steps to West Bend, where they began a permanent settlement. On the 31st day of May, 1855, on the line between the two claims, the first prairie in Palo Alto County was broken with five yokes of oxen.

The first settlement in Clay County was made in July, 1856, by the Ambrose Mead and the Christian Kirchner families, who built cabins in the southwest corner township of the county. In 1857 the Indians on their way to Spirit Lake, just before the massacre, passed through the settlement and destroyed personal property of these families. After this, the settlers in the county left for several months until national troops had driven the Indians farther west.

#### IMPRESSIONS OF THE CLIMATE, VEGETATION, AND WATER

In Plumbe's *Sketches of Iowa* (1839) the climate of this region a hundred years ago is described graphically much as at present by Lieutenant Albert M. Lea, who explored Iowa territory in 1836. His picturesque language impresses the senses with the seasonal contrasts of temperature in a manner which no standard weather report could convey. From the same source appears an article concerning the impressions of the traveller through the prairie. The following extracts from the pen of Judge James Hall refer to the characteristics of Iowa prairie wherever it exists but do not apply exclusively to the northwestern area. From such records only can an image of the prairie be reconstructed.

"The scenery of the prairie is striking, and never fails to cause an exclamation of surprise. The extent of the prospect is exhilarating. The outline of the landscape is sloping and graceful. The verdure and the flowers are beautiful; and the absence of shade, and consequent appearance of profusion of light, produce a gaiety which animates the beholder.

"It is necessary to explain, that these plains, although preserving a general level in respect to the whole country, are yet in themselves not flat, but exhibit a gracefully



waving surface, swelling and sinking with an easy slope, and full, rounded outline, equally avoiding the unmeaning horizontal surface, and the interruption of abrupt and angular elevations. It is that surface which, in the expressive language of the country, is called rolling, and has been said to resemble the long, heavy swell of the ocean, when its waves are subsiding to rest after the agitation of a storm.

"It is to be remarked, also, that the prairie is almost always elevated in the center, so that in advancing into it, from either side, you see before you only the plain, with its curved outline marked upon the sky, and forming the horizon; but on reaching the highest point, you look around upon the whole of the vast scene.

"The attraction of the prairie consists in its extent, its carpet of verdure, and flowers, its undulating surface, its groves, and the fringe of timber by which it is surrounded. Of all these, the latter is the most expressive feature—it is that which gives character to the landscape, which imparts the shape, and marks the boundary of the plain.... Where the plain is large, the forest outline is seen in far perspective, like the dim shore when beheld at a distance from the ocean. The eye sometimes roams over the green meadow without discovering a tree, a shrub, or any object in the immense expanse, but the wilderness of grass and flowers; while, at another time, the prospect is enlivened by the groves, which are seen interspersed like islands, or the solitary tree, which stands alone on the blooming desert.

.....

"In the summer, the prairie is covered with a large coarse grass which soon assumes a golden hue, and waves in the wind like a ripe harvest. The first coat of grass is mingled with small flowers; the violet, the bloom of the strawberry, and others of the most minute and delicate texture. As the grass increases in size, these disappear, and others, taller and more gaudy, display their brilliant colors upon the green surface, and still later, a larger and coarser succession appears with the rising tide of verdure. A fanciful writer asserts that the prevalent color of the prairie flowers is, in the spring a bluish purple, in midsummer red, and in the autumn yellow. This is one of the notions that people get, who study nature by the fireside. The truth is that the whole of the surface of these beautiful plains, is clad throughout the season of verdure, with every imaginable variety of color, from grave to gay. It is impossible to conceive a more infinite diversity, or a richer profusion of hues, or to detect the predominating tint, except the green, which forms the beautiful ground, and relieves the exquisite brilliancy of all the others. The only changes of color observed at the different seasons, arise from the circumstances, that in the spring the flowers are small, and the colors delicate; as the heat becomes more ardent, a hardier race appears, the flowers attain a greater size, the hue deepens; and still a later succession of coarser plants rise above the tall grass, throwing out larger and gaudier flowers. As the season advances from spring to midsummer, the individual flower becomes less beautiful when closely inspected, but the landscape is far more variegated, rich, and glowing."

Reference is made to the clearness of the streams and lakes in a letter written by a citizen of Ohio who compares the streams of Illinois as impure and muddy, but refers to the "bright transparency of the Des Moines," in his description of the rivers. In the *Geology of Iowa*, White (1870, v. 2) refers to the "numerous small lakes of clear water, resting in shallow depressions in the drift." As late as 1909 Gillespie and Steele refer to the Little Sioux as a beautiful stream of serpentine windings throughout seventy-one miles with waters that are clear and silvery, running over rocky and sandy beds.

#### CHANGES PRODUCED BY CULTIVATION

In the eighty-six years which have passed since the first settlement of white men marked the breaking of sod and the thirty years which have



elapsed since the waters have been described as clear, many changes have taken place in the vegetation, soil, and water. The Indian, who removed from the basic natural resources only what he had used for subsistence, has vanished. His race has been replaced by one which has removed the native cover from the soil without caution, permitting the unrestricted passing of the rich surface soils into the lakes and the sea. Though the extent of deposition of Iowa soil in the Gulf of Mexico has not been recorded, data, reported in the meandered stream survey of the Second Report of the Iowa State Planning Board (1935), show that the lake beds have been filled with silt from a depth of 10 to 30 feet. Early records of vegetation are scarce. However, White (1870) states that wild rice abounded around the borders of lakes of northern Iowa. This plant is now rarely seen in the lakes of the region and is with difficulty introduced.

The lakes and rivers which once teemed with apparently inexhaustible supplies of fish, must now be skillfully stocked and tended by a staff of trained workers, in order to maintain for the citizens the sport of fishing. Doubtless the cooperative interest of all Iowans to reduce the pollution and silting of streams would in a measure restore the productivity of earlier times and afford better playgrounds for the people.

#### NATIVE COVER OF STATE PRESERVES COMPARED WITH ADJACENT AREAS

In the well-preserved forest in Wanata State Park along the Little Sioux at Peterson, and at Estherville along the Des Moines River in notably rough topography, an observer may see that moisture is conserved by the accumulated vegetative material deposited annually by large numbers of native wild plants, where they occupy all soil space as they live in locations best suited to their needs. Not only do these plants persist, sharing selectively light, space, soil water, and inorganic food, but they propagate themselves and replace essential elements in the soil. The pattern of their grouping serves as a model to the student of landscape decoration who would employ the native plant in home and wayside planting.

Contrasting with these rare but well-preserved forests are the denuded hills along the course of the Des Moines in Palo Alto County and the Little Sioux in Clay County. Where vegetation has been removed from steep surfaces, top soils have been destroyed by erosion. Moisture-holding organic matter is scarce, ground cover has been destroyed, and the soil does not support adequate pasture herbage. Where the river has been diverted into the dredge ditch, the water swiftly bears the silted load from the county, and after flood times the ground grows rapidly dry with a permanently lowered water table.

Controlled experimental tillage has demonstrated that soils may be retained in place in level to rolling and even hilly topography by use of terracing, grassed waterways, and vegetation-covered stream banks. However, much rough country, both woodland and grassland, can profitably

be conserved for maintenance of wildlife and also to illustrate the native cover which has been so effective in the building of Iowa soil. Such tracts, where cover remains undisturbed, serve as a safeguard against erosion of adjoining tillable lands.

The northern prairie soils, so named because they are the climatic-vegetative product of past ages, are not everlasting. Cultivation removes replacable elements from the soil; but grassless, shallow waterways across fields, and streams bordered with vegetationless banks remove by erosive processes heavy annual loads of regional resources and leave, if unchecked, a prospect of poverty where abundance formerly prevailed. The barrenness of abandoned farms of New England and southern United States illustrates this condition. Even in southern Iowa irreparable damage has occurred.

Though erosive processes in the Wisconsin Drift Area have been relatively slight in the course of hundreds of years before the settlement of the region, in the past century great inroads have been made upon its natural resources. However, the interest of Boys' and Girls' Clubs in ground cover will doubtless become a part of the consciousness of the future farmer concerning the value of native cover, and not only will protective methods be employed in the tillage of arable soil, but the waste of soil resources will be curbed by retaining, wherever possible, the natural vegetation so well fitted to endure the climatic conditions in which it has persisted.

## THE NATURAL VEGETATION

### THE ORIGIN AND DEVELOPMENT

#### PHYSIOGRAPHIC DISTRIBUTION OF VEGETATION

The level of this terrain is not significant in terms of altitude, since the highest point is only about 1,400 feet above sea level (Table 1). Nevertheless it has the aspect of a tableland. The evolution of any climax vegetation unit is the product of a long period of time under cumulative climatic influences, but its local distribution is closely correlated with the physiographic features within its limits. The localized physical environment of plant communities has been shaped in past ages, partly through the sculpturing of ice and the sorting processes of water, and in more recent times by the work of water of precipitation through leaching and further erosive action. Organic changes in soils, governed by the accumulation of generations of plant materials are, in part, influenced by the presence of water, micro-organisms, and aeration; but the relative availability of water is a critical factor in limiting vegetation.

Through the climatic limitations of humidity, the climax vegetation of the true prairie conforms in the course of vast periods of time to a changing pattern, which is a series of stages originating in water and therefore known as the hydrosere succession in which a balanced type of climax grassland replaces all earlier stages. The following discussion will

define the concepts of vegetative units and communities elsewhere referred to in this paper.

#### HYDROSERE ORIGIN OF CLIMAX PRAIRIE

##### *Physiographic Environments of the Hydrosere*

The character of the aquatic plants of the grassland (prairie) is dependent on the origin and nature of the bodies of water in which they grow. Since the aquatic and subaquatic habitats are less easily accessible and utilizable than the plains and hill slopes of the dry land, man has left the lake, marsh, and river vegetation relatively undisturbed so that it is possible to trace the beginning steps of hydrosere succession more readily than it is possible to trace the end stages found in the fragments of true prairie.

A variety of physical environments are encountered. The immaturity of the drainage system accounts for the series of upland lakes intermittently connected with undeveloped drainage channels, which circuitously wind their way to the more definitely developed erosion channels of the two river systems whose branches originate in the divide established by the Altamont Moraine. There are at least three sources of water: the shallow lakes whose waters are relatively static, kettle holes and ponds; the rivers and streams whose waters have currents; and the upland springs, on hilltop or hillside, whose source is subterranean water. Adjoining the margins of these three types of water bodies are areas referable to swamp, marsh, or fen, in which water is less constant.

The elevated position of the upland lakes in relation to the altitude of the river channels may be seen by reference to the following table of altitudes of several towns in Clay and Palo Alto Counties.

TABLE 1  
ALTITUDES IN FEET ABOVE TIDE

Ruthven—1,413	Crippen—1,265	West Bend—1,197
Everly—1,386	Peterson—1,238	Cylinder—1,194
Langdon—1,371	Emmetsburg—1,234	Rodman—1,193
Spencer—1,319	Curlew—1,222	Greenville—1,091
Ayrshire—1,293	Mallard—1,198	Cornell—1,089

The preceding data are taken from Gannett's *Dictionary of Altitudes in the United States* (1899) and from figures of the Minneapolis and St. Louis Railroad in the *Geology of Clay County* (Macbride 1901). It may be noted from the data in the table of altitudes that there is a difference of about 200 feet in the elevation about Ruthven where the highland lakes of the moraine are grouped and the elevation of Emmetsburg which is located on the post-glacial terrace of the Des Moines River. Medium Lake, whose southern margin lies about a mile from the river channel, lies in a plane 50 feet above the river bed, just north of Emmetsburg. The

altitude of Ruthven which is located on the moraine is considerably higher than the altitude of the towns on the drift plains.

#### LIFE FORMS AND ZONATION OF AQUATIC VEGETATION

##### *Submerged, Partly Submerged (Floating Leaf), Reedswamp, and Free-Floating*

Hydrophytic plants, with reference to the emergence of their parts from the water, may be distinguished in several categories: submerged, illustrated by *Ceratophyllum* and *Utricularia*; the floating-leaf, by *Nymphaea* and *Potamogeton*; and aerial-leaved or reedswamp, by *Typha* and *Phragmites*—all of which are rooted in soil. Since these plants occupy differing depths of water, they are usually zoned, though they may extend into water a meter in depth, or toward the land into wet soil. Where the water table is not far below the surface of the soil, plants with submerged shoots having aerial leaves which do not float, but rise into the air, occur, for example, *Sagittaria* and *Alisma*. These are intermediate between the species with floating leaves and the partly submerged reedswamp plants whose leaves are mostly aerial. Besides these life forms, there are the plants which are not rooted in the substratum, but free-floating in the water, and the vegetative shoots of these may be completely submerged, or their leaves may float on the surface, as illustrated by *Lemna* and *Spirodela*.

#### STAGES IN THE HYDROSERE SUCCESSION

These different life forms characterize successive stages of the hydrosere. The submerged plants are the pioneers, and as the soil level is gradually raised toward the water surface by the accumulation of organic debris resulting from the death of individual plants, or by inorganic silting or by both together, they are succeeded by the plants with floating leaves, and these in their turn by reedswamp dominants, until the soil level reaches the water level and aquatic vegetation gives place to marsh (or fen). The particular communities entering into the sere depend upon a variety of conditions, such as the nature of the original substratum, the amount and nature of silting, and exposure to current or wave action. As the water becomes more shallow, it is quieter and warmer. Increased protection is afforded, and the conditions are more uniform, so that the floating leaf dominants are less various than those of the submerged communities. The marsh or fen plants, as the substratum dries, may be succeeded by sedge meadow, wet meadow, prairie climax, and in sheltered places, patches of forests.

##### *Early Hydrosere*

It is difficult to distinguish the lake from the bodies of water associated with it in evolutionary sequence, since a lake may approach, by gradual filling in with vegetation and silting, the stages of swamp or marsh. In the following discussion, the definition of Forel (1892, in part),

will be adopted for a lake and the concepts of Tansley (1939) for swamp, marsh, and fen. The term fen has been confined mostly to European literature in the past, but its counterpart seems recognizable in North American territory.

*Lake.* A lake is an inland body of standing water occupying a basin.

*Pond.* A pond is a lake of slight depth.

In the lake or pond environment, qualities of the water are more significant in their effect upon the plants which grow there than are the qualities of its soil. The following include some of the limitations in an environment of water which conditions the available supply of light, air, heat, and food, both mineral and organic, according to Tansley (1939). The supply of water is ample in small lakes and ponds except in times of drought. Green plants are subject to the hazard of deficiency of oxygen and carbon dioxide as well as mineral nutrients. Rooted aquatics have been shown to be more dependent on nutrient ions absorbed from the soil than on absorption of these from the water surrounding their shoots. Rooted aquatic vegetation, therefore, varies very much in amount and composition according to the nature of the substratum below the water, and this usually depends upon the presence, absence, and the composition of silt. Floating plants are entirely dependent upon the water itself for all of their supplies, and since different waters contain very different amounts of dissolved substances, floating vegetation may be scarce or absent. Decreasing light intensity limits the depth to which green plants can descend on a lake bottom and some can exist with less light than others. Apart from light, the two chief factors affecting aquatic vegetation are the presence or absence of sufficient dissolved oxygen and the deficiency or the adequacy of the mineral salts derived from silt. Where abundant green vegetation has been able to establish itself, photosynthesis amply covers the supplies of oxygen necessary for the respiration of both plants and animals, but in poorly vegetated lakes and rivers the oxygen supply depends largely on solution by currents and wave action. Silt is also one of the most abundant factors, except in ponds situated in rich mineral soil, where abundant nutrients are always present and the floor is covered by a rich organic mud composed of rain wash mixed with humus derived from decayed plant remains. Unless the water is definitely fouled from any cause, a luxuriant aquatic vegetation is maintained. A pool of similar size in a district of hard rock or sterile sand may support a very limited vegetation of specialized type, or be almost barren of life.

*River.* Rivers are subject to less variation than still waters in such factors as temperature and dissolved gases which are critical for the existence and luxuriance of vegetation, but when floods bring down much silt, sweeping away existing vegetation, and increasing turbidity, conditions favorable for the growth of vegetation may change completely in a short time. The vegetation of rivers with a very slow current flowing through alluvial soils resembles that of canals and of ponds and small lakes situated in similar soils. The rate of flow is one factor in the supply of dissolved oxygen.





FIG. 4. Upland prairie in June. New Jersey tea (*Ceanothus ovatus*) and compass plant (*Silphium laciniatum*) in *Stipa-Sporobolus* grassland.





FIG. 5. True prairie; *Stipa-Sporobolus*, upland dominants; *Andropogon-Panicum-Elymus*, lowland.



FIG. 6. Erosion valley of the Little Sioux River above Wanata State Park at Peterson, Clay County. Oak-hickory-maple forest on the protected side of the valley; bur oak in valleys of exposed hills; oxbow cutoff pond in foreground.



FIG. 7. The tree-screened border of Round Lake Wildlife Refuge.

Those communities intermediate between water life forms and land life forms are distinguished as follows:

*Swamp.* Swamp is the type in which the normal summer water level is above the soil surface. It is usually dominated by such plants as *Phragmites*, *Scirpus*, or *Fluminea*. When the soil level rises to or above the water level, marsh plants begin to colonize the swamp, though *Phragmites* by means of its rhizomes often persists into wet grassland associations.

*Marsh.* Marsh is the term applied to a soil-vegetation type in which the soil is waterlogged, the summer water level being close to, or conforming with, but not normally much above, the ground level, and in which the soil has an inorganic (mineral) basis. Marshes commonly occur along river banks or on the shores of lakes and on the undrained floodplains of rivers, and its mineral soil often consists of alluvial silt, but marsh exists wherever mineral soil is waterlogged, irrespective of its origin. Marsh vegetation is commonly zoned around or along any permanent body of water, unless the bank is very steep so that the soil is not waterlogged, for example, *Phalaris arundinacea*, *Alopecurus aequalis*, and *Ranunculus cymbalaria*.

*Fen.* Fen is the term applied to a waterlogged soil vegetation type in which the soil is organic (peat) but is somewhat or decidedly alkaline, nearly neutral, or somewhat, but not extremely acid. The vegetation of a fen is similar to that of a marsh. Where periodic mineral silting is more or less absent, the soil is mainly or entirely organic from the outset, and where the supply of basic ions is adequate the kind of vegetation succeeding the reedswamp is typical fen. The organic soil is formed by the decay of the plant debris under relatively anaerobic conditions, and is therefore peat. Fen peat is formed where the ground water drains from, or is in contact with limestone or marls and thus contains abundance of calcium which neutralizes the organic acids and may render the reaction distinctly alkaline. This condition is illustrated in the vegetation of the upland, hillside springs of the upland prairie. These communities have been referred to as "hanging bogs." In this environment the alkaline water runs through characeous marl, not limestone. Fen plants form black peat, usually structureless, which differs widely from moor or bog peat in its general characters and reaction.

Where the relation of water level to soil level remains approximately stable, marsh (or fen) represents an edaphic climax. But if from any cause the soil surface is progressively built up above the water level or the water table is lowered so that the root systems of the plants are better aerated, the marsh (or fen) vegetation gives way to a more completely terrestrial type—ultimately to a climatic climax, which in the Clay-Palo Alto region is grassland.

### *Late Hydrosere*

Vegetation of soil communities is described by the terminology of Weaver and Clements (1920).

*Sedge meadow.* It is the tendency of reedswamp plants to shade the



surface of the water and to build up shores by retaining the sedimentary materials washed into the water by the rapid accumulation of plant remains, but as the depth of water is decreased, cat-tails, bulrushes, and their associates develop less rapidly, and other species invade their territory. The increasing amount of light in this environment favors the growth of *Carex* (sedge), *Juncus* (rush) and *Eleocharis* (spike-rush) which soon form a dense sod. Such habitats are covered with water in spring and early summer, but later in the year the surface water recedes, leaving the soil saturated. Then, as the soil dries, many herbaceous species invade the *Carex*-*Juncus*-*Eleocharis* zone. Among these are *Mentha* (mint), *Teucrium* (germander), *Stachys* (hedge nettle), *Lycopus* (Bugleweed), *Caltha* (marsh marigold), *Cicuta* (water hemlock), and others (Figs. 31 and 32).

*Wet meadow.* As the sod is established dominant grasses which tolerate drier conditions invade the territory, among which are *Spartina pectinata* (slough grass), *Calamagrostis canadensis* (reed bent grass), *Andropogon furcatus* (tall bluestem), *Elymus canadensis* (canada rye), and *Panicum virgatum* (switch grass). In spaces between the grass colonies grow conspicuous-flowered herbaceous plants such as *Phlox*, *Anemone*, *Thalictrum* (meadow rue), and *Zygadenus* (Fig. 9).

*Prairie climax.* In the more highly developed soils with better drainage and increased organic material, the dominant grasses include *Stipa spartea* (porcupine grass), *Andropogon scoparius* (little bluestem), *Bouteloua curtipendula* (side-oats grass), *Koeleria cristata* (June grass), *Sporobolus heterolepis* (prairie dropseed), and numerous subdominant plants such as species of *Helianthus* (sunflower), *Solidago* (goldenrod), *Liatris* (blazing star), *Lespedeza* (tickseed), and *Petalostemum* (prairie clover (Figs. 4 and 5).

Along the Des Moines River, on protected aspects of the Little Sioux River, and on lake borders, the sedge stage of the hydrosere is followed by shrub and tree stages.

*Shrub stage.* The shrub stage is represented by *Symphoricarpus occidentalis* (snowberry), *Amorpha fruticosa* (false indigo), *Sambucus canadensis* (elderberry), and species of *Cornus*, *Rubus*, and *Ribes*.

*Tree stage.* The tree stage includes various phases in the development of the oak-hickory forest with willows widely distributed along prairie waterways and hickory represented only by *Carya cordiformis* (bitternut) (Figs. 6, 13, and 28).

#### NATURAL VEGETATION AREAS, REFUGES, AND RESERVES OF THE CLAY-PALO ALTO LAKE REGION

##### NATURAL AND PLANNED GAME PRODUCTION AREAS AND REFUGES

Since the lakes and their adjacent territory include areas least modified by the industry of man, it is in and around them that the native flora is most widely preserved (Figs. 5 and 12). In these tracts and others now constituting parts of privately owned farms, a survey of plants useful to waterfowl has been made. Through the courtesy of officers of the Mud



FIG. 8. A dry pond populated with narrow-leaved cat-tail (*Typha angustifolia*), slender bulrush (*Scirpus heterochaetus*), with ground cover of common cocklebur (*Xanthium italicum*). Dewey's Pasture, Palo Alto County.



FIG. 9. A labyrinth of swamps alternating with upland prairie in Dewey's pasture. Wet meadow borders the swamp.





FIG. 10. A meandering, intermittent stream which connects Mud Lake with Trumbull through Smith's Slough. The waterway is marked by bur-reed (*Sparganium eurycarpum*), bordered by reed-meadow grass (*Glyceria grandis*).

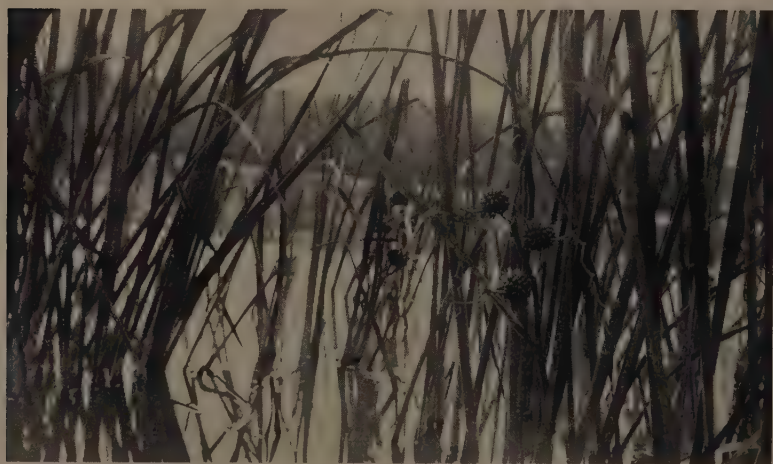


FIG. 11. Greater bur-reed (*Sparganium eurycarpum*) in fruit.



FIG. 12. Upland prairie above Virgin Lake. Side-oats grass (*Bouteloua curtipendula*) and rigid goldenrod (*Solidago rigida*).



FIG. 13. Peach-leaved willow, green ash, and red elm on the walled bank of Lost Island Lake. Shallow pond at left during a period of high water.



FIG. 14. The gravel bank on the northeast shore of Lost Island Lake which marks the post-glacial waterway between Lost Island and Mud (Pelican) Lakes.



FIG. 15. The ice-built, boulder-walled, south shore of Lost Island Lake.

Lake Fur Farm it was possible to include Mud (Pelican) Lake in the survey.<sup>3</sup> Farmers of the region have cooperated by furnishing to the writer local information, as well as permission to work upon their premises. Some of the areas less valuable for agriculture are now preserved by the state as game production areas, or wildlife refuges (Fig. 7). Table 2 shows some of the comparative characteristics of state-owned areas and their uses as designated by the State Conservation Commission. In order to compare the plants found in the Ruthven Area with those of the surrounding territory, the flora of the entire two counties was surveyed, and observations, not reported here, were also made for the northwestern section of Iowa.

This series of shallow lakes with the sloughs and intermittent streams which connect them served formerly as troughlike drainage ways in periods of high water (Figs. 9 and 10). The slow release of water by the intermittent waterways tended to maintain the stability of the ground water table which was formerly several feet higher than it is today. The drainage at the present time is modified somewhat by the construction of dredge ditches and tiling which accelerates the rate of runoff from surrounding territory. The acceleration of runoff, with the removal of cover from the soil, probably accounts for the heavy deposits of silt in the lakes, mentioned in the *Second Report* of the Iowa State Planning Board (1935).

### *The Evolution of Local Maps*

The lakes of Clay and Palo Alto Counties have been variously represented in the early maps. The map of Nicollett in 1845, which was the seventh map of Iowa Territory, showed only Lac des Esprit and Lizard Lake for northwestern Iowa. A map by Johnson and Browning, published in 1859, was the first to insert the group of lakes in Clay and Palo Alto Counties. They were undifferentiated, and the body of water was called Lake Palo Alto.

In the map of J. H. Colton the main lakes were separated but not named, and the rivers were not shown. The township map of G. Woolworth Colton in 1863 represented the present Trumbull and Round Lakes as one body, unnamed. It was not until 1830 that the name, Lost Island, was identified with Lake Palo Alto; Trumbull and Pelican (Mud) Lakes were named for the first time. The plats of the First Government Survey (1868) indicated a waterway about one-fourth of a mile wide joining Mud (Pelican) and Lost Island Lakes on the northeast border, where the present gravel bank is located, on the shore of Lost Island Lake (Fig. 14).

The maps of the geological survey (Macbride, 1901 and 1905) show

<sup>3</sup> Mud Lake (Pelican Lake), just north of Lost Island Lake, covers an area of 560 acres with a watershed of about 15,800 acres, according to the *Iowa Lakes and Lake Beds Survey* (1917). The sources of its water are a small stream entering the lake through swamps at its east side, intermittent streams from Dewey's Pasture, and lake-bed springs. In wet seasons, water flows through the dammed outlet under the highway on the west side of the lake into Smith's Slough, and from there into Trumbull Lake. The sand and gravel of the lake bed are mostly covered by silt and organic detritus. The lake is seldom more than 2 feet in depth.

clearly the intermittent character of the connective streams and main swamps. The maps of lakes, prepared by the Highway Commission (1917) to accompany the report on Iowa Lakes and Lake Beds, exhibited greater detail than earlier maps. They recorded depth of water and contours of adjacent land. In the composite map prepared by Logan Bennett (1938), showing further modifications of the Ruthven Area, the former positions of Elbow Lake and Rossaker's slough are marked. These waterways are now converted to agricultural uses and, therefore, were not shown on the map of the Ruthven Area prepared in 1940 (Fig. 1).

### *The Glacial Lakes of the Altamont Moraine*

*Physiography.* This cluster of hard-water lakes may be grouped in two classes with reference to the water as it affects vegetation: (1) lakes with open water including Lost Island, Silver, Medium, Virgin, Elk, Pickerel, and Rush; and (2) shallow, reedy lakes illustrated by Round (Swan), Mud (Pelican), and Dan Green Slough (Figs. 7 and 30). The open water lakes are subject to wave action, which is most pronounced in the deeper bodies of water such as Lost Island and Virgin Lakes (Figs. 12 and 16). This group is also characterized by walled banks; these are typical of the shallower glacial lakes which freeze to the bottom around the shores or throughout. The formation of the walls are described by White (1870). Material consisting of boulders, gravel, sand, or mud is carried toward shore and left forming a ridge where the expansive power of the ice ceases. Lost Island, Silver, Elk, and Virgin exhibit walls of very regular rip-rapping, reaching 10 or more feet in height (Fig. 15).

*Drainage.* The group of lakes of the Ruthven Area is situated at the edge of the Altamont Moraine, and all drain to the west, through Outlet Creek, into the Little Sioux River. Macbride observed that to the west of them there are not high protecting mounds, but that their marginal position is subject to over-wash deposits of sand and gravel from the edge of the retreating ice. This accounts for the shallowness of Mud (Pelican) Lake and for the series of swamps and marshes through which these lakes find an outlet. The income and outgo of water into the lakes varies with the seasonal water level for the region. Sometimes the water from the outlets runs into the lake until an equilibrium is reached. A dam constructed at the west end of Lost Island Lake to keep the water from running out through the theoretic outlet, actually kept the water from entering; and when a channel was made in the earthen retaining wall, water ran in from the outlet raising the level of the lake several feet. Most of the lakes now have cement spillways.

During the drouth of 1933 and 1934, the unusually dry swamps of the Outlet of Lost Island Lake were transformed into sedge and grass-meadow associations, but in the course of five years, they have undergone reversion stages from sedge and grass meadow to swamp and marsh (Figs. 18 and 19). Correspondingly shallow bays of Lost Island Lake, which had borne reedswamp stages of vegetation, reverted to open water, and the



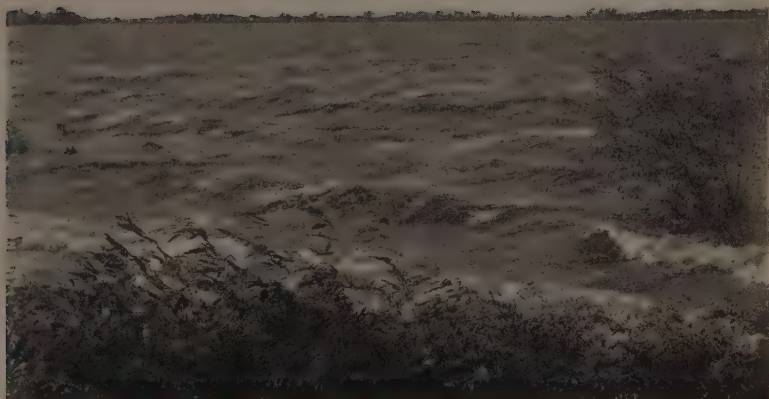


FIG. 16. Lost Island Lake in action. South shore.



FIG. 17. A zone of cottonwoods and willows growing on the south shore of Lost Island Lake in 1934-37, were removed by wave action during the high water level of 1938.





FIG. 18. The Outlet of Lost Island Lake during a period of drouth. Narrow-leaved cat-tail, (*Typha angustifolia*) and common reed grass (*Phragmites communis*) extending their domain over the dry marsh floor, which is mulched by dried algae.



FIG. 19. Outlet of Lost Island Lake, in swamp stage.

lake bed again supported rooted, submerged vegetation. Zones of willows and cottonwood succumbed to wave action and disappeared as the 40 feet of sandy beach was again covered by water and the waves beat again upon the boulder-walled banks (Fig. 17).

*Vegetation.* The flat-bottomed open lakes like Trumbull, Elk, and Silver support much submerged vegetation such as Narrow-leaved Pondweeds (*Potamogeton* and *Najas*). In shallow bays, where the standing water is clear, and in the shallow lakes such as Round and Mud occur other stages of emergent vegetation (Figs. 20 and 22). The chief floating-leaved species is the American pondweed (*Potamogeton americanus*). Free-floaters are represented by the duckweeds including *Lemna*, *Spirodela*, and *Wolffia*. The partly emersed and partly air-leaved plants include species of *Sagittaria cuneata*, *S. latifolia*, *Alisma subcordatum*, and *Lophotocarpus calycinus*. Among the plants of the reedswamp stage are the pale great bulrush (*Scirpus heterochaetus*) and the soft-stemmed bulrush (*S. validus*) near the shores or in shallow ponds and swamps, associated with the narrow-leaved cat-tail (*Typha angustifolia*) (Fig. 8), and the reed grass (*Phragmites communis*) in deeper waters. These silt-bottomed lakes which support rooted vegetation have little wave action and are very clear. They sustain a luxuriant vegetation providing food, cover, and nest-building materials for waterfowl, which frequent such communities. The clearness of the water may be accounted for by the presence of rooted vegetation which anchors the silt.

The vegetation seldom remains static, for variations in the water level result in succession stages. Muskrats periodically clear areas of the reedswamp vegetation, which is usually replaced by a crop of pondweeds, either submerged or floating. Very low water revealing mud flats favors marsh colonies of smartweeds (*Polygonum*) (Fig. 24), *Lophotocarpus*, and such annual land plants as barnyard grass (*Echinochloa crusgalli*), species of spike rush (*Eleocharis*), and red goosefoot (*Chenopodium rubrum*). Temporary fluctuations in water levels merely produce rotation of water crops, which should provide a variety of food plants, but change the relative position of the cover plants.

Around the lakes are terraces whose sandy and gravelly soils mark the position of shores during higher post-glacial water levels. Here grow certain species of plants which are typical of lake shore, among which are the Baltic rush (*Juncus balticus* var. *littoralis*) and the rayless aster (*Aster angustus*).

#### THE PRAIRIE

On the windward side of the lakes, few or no trees grow. The prevailing winds, and particularly those of winter, are from the northwest. Commonly the grass-covered banks occur on this side. An occasional section of natural prairie occurs in the northwest of Iowa, but an area that large is seldom seen in Clay and Palo Alto Counties. On the east side of Medium Lake, midway along the lake, is a well-preserved strip of tall-grass sod-prairie in which *Andropogon furcatus* is conspicuous (Fig. 25).

On the hills above Virgin Lake, some highland sod persists, including a considerable number of distinctive plants of the northern true prairie. In Logan Township, section 15, a bunch-grass type on rocky, gravelly soil borders Elk Creek. Several upland types of prairie remain on the hills above Gillett grove and along Elk Creek. Perhaps the most impressive bunch-grass prairie dominated by little bluestem or prairie beardgrass (*Andropogon scoparius*) covers the rocky hills. From the hilltops overlooking the forested valley of the Little Sioux River, may be seen ridge after ridge of grass-covered hills bearing bur oak groves on their leeward sides. In spring, carpets of pasque flower (*Anemone patens*) lend a bluish cash to the red-brown hilltops, which blends with the haze of the distant valley. All through the season, a sequence of brilliant-colored flowering plants spring up among the grasses (Figs. 27 and 28).

Still another type is seen between the railroad right-of-way and Highway 17, along the highway in the vicinity of Graettinger, and elsewhere on the post-glacial gravelly terrace of the Des Moines River. This is a bunch-grass community which is dominated by June grass (*Koeleria*



FIG. 20. Arrowhead (*Sagittaria cuneata*) with hard-stemmed bulrush (*Scirpus acutus*) and greater duckweed (*Spirodela polyrhiza*) in Round Lake.



FIG. 21. Narrow-leaved cat-tail (*Typha angustifolia*), a conspicuous plant of Round Lake.

*cristata*) and the dropseed grasses (*Sporobolus heterolepis* and *Sporobolus asper*). Occurring on knolls in the vicinity are the Pennsylvania sedge (*Carex pennsylvanica* var. *digyna*) and the involute-leaved sedge (*C. Eleocharis*). This assemblage is characteristic of the bunch-grass prairie of a drier western climate.

In Palo Alto County are two state-owned preserves, which could serve as a haven for wildlife, a place to study grassland as well as to illustrate the phenomenon of Iowa's primeval vegetation which required many centuries in the making. One area lies on the northeast bank of Rush Lake, facing the tree-fringed rocky south shore. This is a typical prairie-covered shore of a wind-swept lake fashioned through the centuries by slow-moving and mighty forces. Yet, by the recent introduction of exotic trees arranged with geometric precision, this work of the glacial ages has been rendered meaningless by the misplaced planting of trees in a climax prairie.

On the east bank of Lost Island Lake is located a small park, which includes a portion of the rock-walled lake, banded by a border of hardwood trees including a bur oak grove (Fig. 26). A grassy slope sweeps upward from the tree-fringed lake. The grassland is brilliant in June with many prairie roses of several species. Much of the high grassland has recently been planted thickly with flood plain trees, mainly cottonwood and maples. Not only are the trees planted in an exposure unnatural to them, but the esthetic balance and the biological significance of the grassland, in contrast with the narrow border of trees on the lake bank, is destroyed. Such plantings are out of place.

### *The Invading forest*

The broad-leaved forest formation is sparsely represented in Iowa and follows the streams into the state from the southeast, becoming less conspicuous toward their upper limits, until in the northwestern part of the state many of the streams run treeless through the prairie (Fig. 28). In moist depressions in the open prairie grow low, bushy willows including solitary, round-topped trees of the prairie willow (*Salix humilis* var. *rigidiuscula*), and the beaked willow (*S. rostrata*). On sheltered shores grow low groves of the downy thornapple (*Crataegus mollis*); or solitary and round-crowned, they are seen at the edge of woods and along the valleys. The round-leaved thorn (*C. chrysocarpa*) is seen on roadsides and border of woods, its fruits turning scarlet in mid-August. Conspicuous on gravelly knolls are gnarled clusters of the prairie thorn, twisted by the winds—the first thorn to flower in spring and laden with cherry-red fruits early in September.

The rocky bank of the walled lakes is usually banded by a zone of hardwood trees and shrubs. The prairie thorn (*Crataegus pertomentosa*), the chokecherry, and the wild plum are most common (Fig. 30). The most prominent hardwood is the bur oak (*Quercus macrocarpa*) which spreads out in groves. The green ash (*Fraxinus pennsylvanica* var. *lanceolata*), with occasional trees of hackberry (*Celtis occidentalis*) and



FIG. 22. Floating and emergent plants in Round Lake; American pondweed (*Potamogeton americanus*), broad-fruited bur-reed (*Sparganium eurycarpum*), hard-stemmed bulrush (*Scirpus acutus*), and arrowhead (*Sagittaria cuneata*).



FIG. 23. A saucer-like pond among morainal hills.





FIG. 24. The floating form of water smartweed (*Polygonum natans forma genuinum*) which grows in lake, pond, marsh, swamp, wet meadow, or dry land.



FIG. 25. Tall beardgrass (*Andropogon furcatus*) and prairie beardgrass (*A. scoparius*) on a prairie knoll.



the peach-leaved willow (*Salix amygdaloides*), grow along the banks. They occupy the lower shores where boulders lie embedded or scattered along the beach (Fig. 13). The rock-bound, eroding banks where the groves are located are usually on the northeast and southwest shores and mostly span the leeward bays. The long axis of the groves extend in a direction parallel with that of the prevailing winds. Around the protected lakebanks and on islands in Medium and Virgin Lakes are small groves (Fig. 12) where, as herbaceous ground covering, grow Dutchman's breeches (*Dicentra cucullaria*), blue phlox (*Phlox divaricata*), waterleaf (*Hydrophyllum virginianum*), columbine (*Aquilegia canadensis*), and the violets (*Viola sororia*, *V. septentrionalis*, and *V. scabriuscula*).

The most notable forest development of the two counties borders the Little Sioux at Peterson (Fig. 6). A tract of 136 acres is known as Wanata State Park. It lies in the first sheet of the Wisconsin drift (Iowan). This forest association is not a part of the Prairie Climax vegetation but may be regarded as an invasion of the broad-leaved forest which extends into the eastern half of Iowa, where the average rainfall is above 32 inches. Few trees mark the shallow course of the Little Sioux as it winds sluggishly through its alluvial plain. As it cuts through the gravels of the



FIG. 26. A bur oak grove bordering the east bank of Lost Island Lake, in Lost Island State Park, wild roses in the grassland.

morainic hills in the vicinity of Gillett Grove, and after it is reinforced by the waters of Willow Creek, it channels ever more deeply through the plain, where it functions as an erosion stream. From this point onward, the river is bordered by a dense but narrow band of forest, which is well developed on the sides of the precipitous but sheltered bluffs of clay rising as much as 200 feet above the river bed.

The oak-hickory forest developed on the second lobe of the Wisconsin (Iowan) Drift at Peterson resembles in floristic aspects the Early Wisconsin (Iowan) in eastern Iowa, though some species of the oaks and hickories have dropped out. The oak-hickory and maple-basswood dominants shelter a considerable number of secondary woody plants including gooseberry (*Ribes*), arrowwood (*Viburnum*), honeysuckle (*Lonicera*), burning bush (*Evonymus*), and dogwood (*Cornus*).

On the borders of the maple-basswood association and in open spaces of the floodplain, the flat-topped dotted thorn (*Crataegus punctata*) is frequent. Here and there in woodland borders of the valley are trees of the woolly thorn (*C. calpodendron*). On open floodplains, woodland borders, and terminals of small streams grows the round-crowned, glossy-leaved, long-spined thorn (*Crataegus succulenta*). The black walnut (*Juglans nigra*), is frequent, and Kentucky coffee bean (*Gymnocladus dioica*) occurs in the narrow valley.

The herbage of this forest association includes a wide range of mesic plants native to the eastern, also the northern broad-leaved forests. Snow trillium, drooping trillium, large-flowered bellwort, hepatica, spring beauty, bloodroot, dogtooth violet, ginseng and wild sarsaparilla, bedstraw, and violets make luxuriant growth.

In Palo Alto County, the woodland, except the lake-bank groves (Figs. 12 and 26) is poorly represented, since pasturage has removed the native undergrowth on the hills, baring them to erosion forces; and the native cover of the alluvial valleys is replaced by invading ruderals. The river road between Graettinger and Emmetsburg affords a wide vista up the valley of the Des Moines River, which is fringed with oak-hickory on the west and bordered on the east by an alluvial floodplain about two miles in width. Below Emmetsburg, the river winds through the plain which widens to about four or five miles, and then contracts to a width of a mile before it leaves the county near West Bend. The prairie flora of the terraced post-glacial floodplain bounding the present river floodplain has elsewhere been described. The native plants remaining indicate that the woodland flora resembled that of the well-preserved areas in the vicinity of Estherville in Emmet County. Here, as well as in Clay County, the only hickory present is the bittersweet (*Carya cordiformis*). The Juneberry (*Amelanchier arborea*) in bur and red oak woods is occasional on the upland, and the flood-plain trees include green ash, black ash, box elder, black walnut, and hackberry. The best preserved spots of this valley are the many and various hillside spring marshes, which occupy areas from one-tenth to an acre in size. They occur in the basswood-maple zone near the base of hills, and some are quarter of a mile long and maintain

a luxuriant growth of "bog" and marsh plants throughout the season. This is the only vegetation in the vicinity about which hogs have shown no curiosity. Surrounded by dry, over-grazed, or bare soil, this unusual mingling of plants of northern floras and plants of transcontinental floras grow luxuriantly.

*Spring or Fen Vegetation—"the Hanging Bog"*

In the open prairie or along rivers in locations of poor drainage, where cold water seeps from the soil on side hills or on knolls, are waterlogged soil communities of water plants. The water table is close to the ground level and remains so during the season. The water is neutral to alkaline in character. In areas of standing water are seen the reedswamp plants, *Typha latifolia*, *Phragmites communis*, and *Scirpus validus*. A sedge zone contains *Carex prairea*, *C. interior*, *Eriophorum angustifolium*, *Caltha palustris*, *Carex strictior*, *Pedicularis lanceolata*, *Gentiana procera*, *Viola neprophylla*, *Aster umbellatus*, *Eupatorium perfoliatum*, *E. maculatum*, and *Parnassia glauca* (Figs. 31-34). In a rush plain we found *Scirpus americana*, *Rhynocospora capillacea*, *Triglochin maritima*, *T. palustris*, and *Lobelia kalmii*. Miniature pools in the rush plain are filled



FIG. 27. Pasque flower (*Anemone patens* var. *wolfgangiana*), the first flower of spring on the prairie. (Photo by Dr. J. N. Martin.)



FIG. 28. Pasque flowers on a prairie knoll. Willows bordering prairie waterways.



FIG. 29. Common reedgrass (*Phragmites communis*) bordering Mud Lake. Bladderwort (*Utricularia vulgaris* var. *americana*) submerged in the water.



FIG. 30. The prairie thorn, *Crataegus succulenta* var. *subtomentosa* on the wind-swept north shore of Mud Lake.



FIG. 31. Cotton grass (*Eriophorum angustifolium*) around the margin of a prairie spring in Palo Alto County. Sedge-meadow community.





FIG. 32. Marsh marigold (*Caltha palustris*) and prairie sedge (*Carex prairea*) at the summit of a spring in Palo Alto County. Sedge-meadow community.



FIG. 33. A pastured marsh, bordered by hillside springs, near the inlet to Lost Island Lake. The hummocks were built by the rootstocks of the tussock sedge now removed by grazing.



with *Chara vulgaris*. Underlying the surface are layers of deep, black peat of alkaline character. These colonies are commonly called bogs, but because of the nature and manner of formation of the peat the community might better be called a fen, to distinguish it from the typical acid moss bog. In sedge-rush fens of the true prairie, shrubs seldom grow with the exception of an occasional willow. The constituent plants are mostly representative of Canadian or boreal floras. These relict colonies appear to be characteristic of the true-prairie climax and differ from the bogs described by Pammel (1909) for eastern Iowa which are typical of the forest transition.

A similar type of sedge fen occurs along the wooded slopes of the Des Moines River, but the succession includes more of the woodland



FIG. 34. The sedge zone around a hillside spring. Flat-topped Aster (*Aster umbellatus*), lesser fringed gentian (*Gentiana procera*), and grass of Parnassus (*Parnassia glauca*) in the foreground.

herbage with such shrubs as *Cornus obliqua* and *Fraxinus nigra*, *Salix discolor*, var. *eriocephala*, and *S. rostrata*.

## THE FLORA

### REPRESENTATION AND SOURCES

The plant survey of any region is concerned with two aspects of the plant population: the distribution of species, genera, and families as they constitute phylogenetic entities or floras, for example, the fern flora, the algal flora; and the distribution of the natural assemblages of plants called vegetation. The structure, development, and illustrative aspects of the vegetation have been reviewed. In the following treatment of the Algal, Moss, Fern, and Seed-plant floras, some biological and taxonomic aspects will be discussed.

The plants collected in this survey include 943 species and varieties composed of 818 seed plants, 9 ferns, 62 mosses, and 54 algae. The fern flora is probably representative for a prairie environment where woodland is scarce. The algae reported are but a fraction of the population, but even a few of these, it will be seen, affect appreciably the growth of surrounding plants. Tiffany (1926) recorded about 200 species of algae for the Okoboji region, Smith (1926) reported about 200 species of plankton, and Prescott (1931) listed additional species.

As to occurrence of species, the following comparison may be made for the flora of Emmet County which is adjacent. Wolden (1932) records 855 species including observations made by Cratty as early as 1904. Conard and Wolden (1932) list 128 mosses and 16 liverworts for the thirteen counties surveyed in the Okoboji region. One hundred mosses and 14 liverworts are recorded for Emmet County.

To a certain extent, the invading associations of the major geographical vegetation units surrounding the climax prairie are a clue to the source of the floristic constituents of a Wisconsin Drift Lake District, which in the present case is a political unit, forming a section of the lake region. The chief vegetation units which have representation within the true-prairie association of the climax grassland formation include the eastern and the northern deciduous forests, the grassland short-grass-plains flora, and boreal-relic colonies.

The plants of the Wisconsin Drift Region have colonized the soil since the departure of the last glacier. During the southward advance of the ice, the then existing vegetation was driven southward, eastward, and westward. The gradual return of the vegetation from other established vegetative centers, halted by fluctuations of climate, local barriers, and limiting climatic and edaphic influences, was a slow process stretching out through centuries. In addition to the integrating influx of plants, many of the plants of the Wisconsin Drift Region appear to differ from the ancestral forms from which they probably developed. Such forms typical of the prairie constitute a flora endemic to the prairie.

TABLE 2  
STATE-OWNED GAME PRODUCTION AREAS, WILDLIFE REFUGES AND RESERVES  
OF CLAY AND PALO ALTO COUNTIES

Name	County	Use of Area	Size	Depth	Watershed
*Lost Island Lake.....	Clay and Palo Alto	Public shooting and Wildlife refuge	1,260 A.	12-16 ft.	59,000 A.
Trumbull Lake.....	Clay	Public shooting	1,190 A.	5 ft.	30,000 A.
Medium Lake.....	Palo Alto	Public shooting	1,106.42 A.	3-5 ft.	Small
Outlet of Lost Island L. (Barringer's Slough)	Clay	Public shooting	1,005.15 A.	1-3 ft.	.....
*Silver Lake.....	Palo Alto	Public shooting and Wildlife refuge	638 A.	5-7 ft.	7,120 A.
Rush Lake..... Dry 1894 Has been dredged	Palo Alto	Public shooting	460 A.	3-6 ft.	.....
Round Lake..... (Swan Lake) Dry 1894	Clay	Wildlife refuge	450 A.	2-4 ft.	18,000 A.
Dewey's Pasture..... Upland with ponds, kettleholes, and fens	Clay	Public shooting	401.66 A.	0-2 ft.	.....
Dan Green Slough.....	Clay	Public Shooting	340.37 A.	4-6 ft.	2,753 A.
Elk Lake.....	Clay	Public shooting	261 A.	4-6 ft.	2,048 A.
Mud Lake.....	Clay (Garfield Twp.) (Sec. 35)	Wildlife refuge	251 A.	Drained	.....
*Virgin Lake.....	Palo Alto	Public shooting and Wildlife refuge	200 A.	5-8 ft.	.....
Pickereel Lake.....	Clay and Buena Vista	Public Shooting	176 A.	4-6 ft.	840 A.
Wanata State Park....	Clay	Forest reserve	145.46 A.	.....	.....
Rush Lake State Park..	Palo Alto	Lake reserve	84.82 A.	.....	.....
Lost Island State Park..	Palo Alto	Lake reserve	27.57 A.	.....	.....
Oppedahl Tract.....	Palo Alto	Public shooting	97.64 A.	0-1 ft.	.....
Schlosser's accession....	Palo Alto	A zone of free access to the lake shore	750 ft. of lake frontage on the north side 1.96 A.		

\* Public shooting area from shore or emergent vegetation 50 yards out into open water, but wildlife refuge on open water 50 yards from shore or emergent vegetation.

Drainage		Retaining Wall	Nature of Bottom
Inlet	Outlet		
Brown's Slough (SE.), also many lake bed springs (Ia. Geol. Sur.)	Outlet Creek	Concrete dam	Silt over sand, gravel, and clay
East side, Smith's Slough; southwest slough; north, drainage ditch	Outlet Creek	Concrete dam	Hard in center, gravel shores
Only small rivulets	Cylinder Creek; old outlet to Des M. River at Emmetsburg	Concrete dam	Silt over sand, gravel, and clay
Lost Island Lake and small streams	Outlet Creek	Concrete dam	Silt and organic matter
3 springs on west; drainage ditch; tile ditches	Willow Creek	Concrete dam	Silt over sand, gravel, and clay
Dredge ditch	Cedar Creek	Concrete dam	Silt and organic matter
From Trumbull Lake; slough to south	Formerly on west side; now through Trumbull Lake	Open channel into Trumbull Lake	Silt and vegetable material
Run off from upland and some springs	Trumbull Lake and Mud Lake	Earthen dams at four sloughs which drain into Mud Lake	Peat and muck
Tile ditches	To Outlet Creek	Concrete dam	Black silt and organic matter
Slough NE. mostly tiled; Ruddick's and Whitman's Slough on S.	Outlet Creek	Concrete dam	Silt and organic matter
Two bays on south which have intermittent streams; two marshes on E. and NE.	Originally into Elbow Lake, (drained); now dredge ditch into Outlet Creek	Concrete dam	Rocks, gravel, clay, silt, and organic matter
One slough on north-west	To south Cedar Creek	Concrete dam	Black silt over sand and clay
of Lost Island Lake.			

## DISTRIBUTION AND ECONOMIC SIGNIFICANCE

## THE SEED-PLANT FLORA

*Sources*

The true prairie climax includes plants from various phytogeographic units. Since a vegetation is the product of a climate, the units might appropriately be named in plant terms, but plant geographers are not in agreement as to the names applied to the principal vegetative areas through North America, nor is the individual history of each plant known. The following table will show the general trends in the distribution of the vascular plants collected in this survey. It is a modification of Merriam's North American life zones adapted and described by Rydberg (1931) as a basis for the distribution of plants described in his manual (1932).

Of the 818 seed plants collected in the present survey, 204 are introduced from Eur-Asian or South American sources and have become associated with Iowa flora after settlements were established. Their advent in northern Iowa was much later than in the southeast where the tillage of soil began. Among this group are some of the most troublesome weeds of cultivated crops. The Canada thistle (*Cirsium arvense*), wild carrot (*Daucus carota*), and European morning glory (*Convolvulus arvensis*) are becoming widely established. In addition to the introduced weedy



FIG. 35. A pothole pond in the prairie bordered by a zone of spikerush (*Eleocharis calva*), with the diffuse tussock sedge (*Carex stricta* var. *strictior*), soft-stemmed *Scirpus validus*, and river bulrush (*Scirpus fluviatilis*) in center.

plants, there are fifty-nine native plants which have escaped from native vegetative areas; generally, when the ground has been broken. When freed from the restraints of competition in their stable native associations, they vigorously invade cultivated land favorable for their growth. One of these is the horse nettle (*Solanum carolinense*), an east temperate plant which has travelled westward and southward from the northeast states through Missouri, the eastern half of Kansas to Nebraska, and has spread throughout Iowa in about forty-nine years. Others find their way into over-grazed pasture. Well known in this capacity are the hoary vervain (*Verbena stricta*), the lesser ragweed, (*Ambrosia artemisiaefolia* var. *elator*), and yarrow (*Achillea millefolium*).

TABLE 3

THE GEOGRAPHIC REGIONS FROM WHICH THE FLORA OF THE CLAY-PALO ALTO LAKE DISTRICT WAS DERIVED BY MIGRATION

Arctic to Cold Temperate	Temperate—	Trans-continental	Temperate to Tropical
Arctic .....6	Allegheny .....158	W. Temperate ....19	Lower Austral
Alpine .....18	Montane .....83	Temperate .....183	Ozark (12)
Boreal .....48	Sub-montane ....206	E. Temperate ....219	Gulf (6) .....18
Canadian .....125	Great Plains .....322	Cen. Prairie .....121	Sonoran (arid) ....11
			Tropical .....21
			Subtropical .....7

### Origin of the Prairie Flora

The plants of the Wisconsin Drift region have colonized the soil since the retreat of the last glacier within the last 25,000 years. During the southward advance of the ice the vegetation existing there must have migrated southward, eastward, and westward. The gradual return of the vegetation, in post-glacial time, from other established vegetative centers, halted by fluctuations of climate, local barriers, and limiting edaphic influences was a slow process stretching out through centuries. In addition to the migrating influx of plants of early origin many of those of the Wisconsin Drift region appear to differ from the ancestral forms from which they probably developed. Such forms, typical of the prairie constitute a flora endemic to the true prairie. They may appear distinct from species growing on unglaciated lands or they may represent the gradational concepts designated by the terms subspecies, varieties, or even ecospecies. Mingled with the prairie flora existing in relatively recently developed climatic and edaphic environment are the floristic elements from other well-established vegetation centers.

### Northern Floras

Nearly 200 species of the prairie flora are plants indigenous to northern regions. They are thought to represent remnants of northern floras



which probably occupied this region after the ice retreated. The floras which populate the fens and swamps of peat formation are largely boreal (arctic, Hudsonian, alpine, and Canadian), in origin. Among the boreal plants are the great bulrush (*Scirpus heterochaetus*), mare's tail (*Hippurus vulgaris*), buck bean (*Menyanthes trifoliata* var. *minor*), the pondweeds (*Potamogeton natans*, *P. zosteriformis* and *P. richardsonii*). These and many others of the northern floras are well-known as food of waterfowl and reach their greatest abundance or even their southern limits, in Iowa, within the Wisconsin Drift. Among them are many sedges and grasses, including *Carex lacustris*, *C. prairea*, *C. substricta*, *C. sartwellii*, *Phalaris arundinacea*, and *Calamagrostis canadensis*.

Transeau (1903) concluded from his series of bog studies made in the deciduous-forest transition region that the "bog" societies of that region resemble those typical of North America, Europe, and Asia; and since the vegetation is composed of boreal species, the societies must be regarded as relicts of former climatic conditions. The bogs of the climax prairie, though not including woodland types, are populated by boreal plants and thus belong to the same general category as relict floras.



FIG. 36. Nest of a redhead duck in a tuft of tussock sedge growing in a prairie pothole pond.



FIG. 37. A ground cover of haircap moss (*Polytrichum commune*).

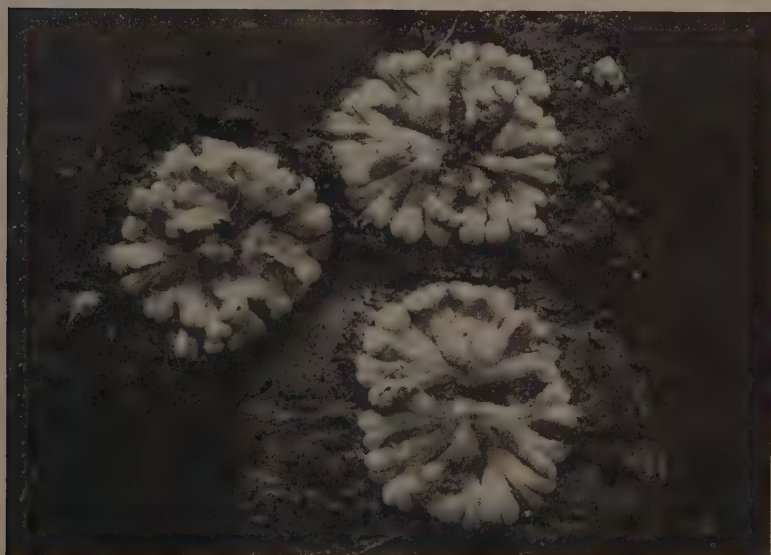


FIG. 38. A liverwort; *Ricciocarpus natans*, the land stage of the purple-fringed *Riccia*. (Photo by Dr. J. N. Martin.)

The flora of hydrophytic vegetation forms of fen and swamp character have significance as producers of peat. Dachnowski-Stokes (1920) stated that progress in peat investigation has been severely checked by widespread use of the terms muck, overflowed land, swampy land, wet land, and others, resulting in the lack of adequate classification of peat deposits. In 1933, he described the belt of peat deposits which border the great lakes and reach from the Atlantic coast to Dakota as mesotrophic. The layers of this fibrous peat are derived from reed and sedge marshes and reedy materials from swamp forest of mixed conifers and hardwoods; they may be (1) either alkaline or acid, as distinguished from the (2) acid moss peat (oligotrophic) of the northern and northeastern states, and the (3) fibrous, alkaline peat (eutropic) derived from grass-marsh vegetation of the Mississippi Valley and Coastal Plain, which are subject to periodic flooding.

In order to avoid land waste it seems advantageous to have all lands not far removed from the peat derivative stages carefully tested before they are claimed for tillage, since many have proved unfitted for agricultural use. This procedure is in accord with the recommendation of Dachnowski-Stokes (1939) favoring the restoration of unproductive and abandoned peatlands located strategically with reference to coastal and continental flyways, since this would re-establish resting, feeding, and breeding grounds for wildlife, insure the conservation and use of peat resources for purposes to which they are best adapted, and elsewhere make an important contribution to the program of submarginal land retirement.

Though the "bog" or fen flora composed of boreal and Canadian plants is very restricted in range within the true prairie, and recurrent locally, other plants of northern origin have wide ranges of distribution. Kentucky bluegrass (*Poa pratensis*), so widely known in temperate North America in meadows, fields, and woods, is a cosmopolitan plant indigenous to arctic and mountainous regions of Europe, Asia, and circumpolar North America (Polunin 1940). It is widely cultivated for hay, lawn, and pasture and has invaded most of the prairies where it is not native. In hilly prairie which has been grazed, grasses and other herbage persist on the hilltops, but *Poa pratensis* claims the alluvial areas and lower slopes of hills, particularly on calcareous soil.

Plants from southerly floras are less common in northern Iowa than in southern Iowa. Nevertheless, the casual observer might be less conscious of 100 inconspicuous unarmed plants of the plains in a community than by the presence of the sandbur (*Cenchrus pauciflorus*) from the Mexican Plateau and coastal region of tropical America which, because of its spines, is able to arrest attention. The grasses of the true prairie are fewer in number than the broad-leaved seasonal forms—the violets, strawberries, phloxes, and lilies; but the grasses are dominant and occupy more space than the species which come and go through the seasons, or even the goldenrods and sunflowers which, like the grasses, persist through the season.

*Plants Useful to Waterfowl*

In general terms, the whole flora is significant as cover, for it is characteristic of the true prairie. Bennett (1938) regards the true prairie plants as excellent cover for the Blue-winged Teal but states that in northwestern Iowa not more than 1 per cent of the true prairie remains, and this is in plots usually not more than 10 acres in size. The prairie most valuable for waterfowl lies close to water of ponds, sloughs, potholes, or swamps, though Bennett has found nests of the Blue-winged Teal a mile away from water (Figs. 35 and 36). Since the native vegetation has been largely removed, he states that bluegrass (*Poa pratensis*) is the chief nesting cover for the Blue-winged Teal. Regions in close proximity to the lakes showed that alfalfa was used for nests where other cover was not available, though with many casualties to the birds. Reeds swamp and wet-meadow vegetation is much more intensively employed by waterfowl for shelter and nesting than is upland vegetation (Figs. 8 and 9).

About seventy plants included in the list of flora contribute to the recognized food of waterfowl, as listed by McAtee (1939), Martin and Uhler (1939), and Hotchkiss (1936). Some of these are plants native in boreal regions, but the majority of swamp plants of northwestern Iowa belong to transcontinental floras. A few species, for example, inland wild rice (*Zizania aquatica* var. *interior*) and river grass (*Fluminea festucacea*), appear to be indigenous to the northern prairies of North America though *Fluminea* also occurs in Eurasia. About fifty of these are of major importance because of the regularity of the crop and their distribution: Slender naiad (*Najas flexilis*), Guadalupe naiad (*N. guadalupensis*), American pondweed (*Potamogeton americanus*), leafy pondweed (*P. foliosus* var. *macellus*), grass-leaved pondweed (*P. gramineus* var. *graminifolius*), common floating pondweed (*P. natans*), panormitanic pondweed (*P. panormitanus*) sago pondweed (*P. pectinatus*), clasping-leaved pondweed (*P. richardsonii*), eel-grass pondweed (*P. zosteriformis*), horned pondweed (*Zannichellia palustris*), water plantain (*Alisma subcordatum*), large lophotocarpus (*Lophotocarpus calycinus*), arum-leaved arrowhead (*Sagittaria cuneata*), waterweed (*Anacharis canadensis*), freshwater eel-grass (*Vallisneria spiralis*), barnyard grass (*Echinochloa crusgalli*), river grass (*Fluminea festucacea*), tall manna grass (*Glyceria striata*), American manna grass (*G. grandis*), rice cutgrass (*Leersia oryzoides*), sprangle-top (*Leptochloa fascicularis*), awned sedge (*Carex atherodes*), Emory's sedge (*C. emoryi*), lake sedge (*C. lacustris*), smooth-sheathed awned-sedge (*C. laeviconica*), woolly sedge (*C. lanuginosa*), slender sedge (*C. lasiocarpa*), beaked sedge (*C. rostrata*), yellow nut grass (*Cyperus asculentus*), needle spike-rush (*Eleocharis acicularis*), spike rush (*E. calva*), pale spike-rush (*C. macrostachya*), blunt spike-rush (*E. obtusa*), and small spike-rush (*E. parvula* var. *anachaete*), river bulrush (*Scirpus fluviatilis*), hard stem bulrush (*S. acutus*), water stargrass (*Heteranthera dubia*), acuminate-leaved water smartweed (*Polygonum coccinea*), blunt-leaved water smartweed (*P. natans*), swamp smartweed (*P. hydropiper*),



dock-leaved smartweed (*P. lapathifolium*), coon-tail (*Ceratophyllum demersum*), American lotus (*Nelumbo pentapetala*), yellow pond-lily (*Nuphar advena*), mare's tail (*Hippurus vulgaris*), water milfoil (*Myriophyllum spicatum*), buckbean (*Menyanthes trifoliata* var. *minor*), greater bladderwort (*Utricularia vulgaris* var. *americana*).

#### THE FERN FLORA

The ferns of Clay and Palo Alto Counties so far recorded include nine species; four of the horsetail and five true ferns. The horsetails have a wide distribution ranging from boreal-arctic, montane, to temperate regions, and commonly occur in the environs of the prairie. The other four ferns are plants of rich woodland and could occur within the limits of a climax prairie formation, only in such environment as the localized broad-leaved forest could provide.

The species found here appear to be plants of wide distribution. Rattlesnake fern, *Botrychium virginianum* and the maiden-hair *Adiantum pedatum*, both occur in Eurasia; the former ranges in rich woods from north temperate to tropical regions, and the latter from boreal to sub-tropical regions. The fragile fern (*Cystopteris fragilis*) occurs in plain, alpine, arctic, temperate, and tropical floras of North America and is also in the Old World. The ostrich fern (*Pteritis nodulosa*) occurs in east temperate regions. It is reported as far west as North Dakota.

The ostrich fern and the lady fern were once very abundant in Wanata State Park but were gathered in quantities for decorative purposes until they became practically extinct, except as they had increased in gardens of residents of Peterson. Through the initiative of the Little Sioux Conservation Club, residents of Peterson, and with the assistance of the organized Boy Scouts, 250 ferns were reinstated in Wanata State park. Such restorative work in natural preserves is very valuable, when it is first ascertained, as was here done, that the introduced plants originally grew in the area and were a constituent part of the flora.

#### THE MOSS FLORA

The survey of mosses and liverworts includes soil builders, soil and water holders, climatic indicators, fauna shelters, and food constituents. Mosses appear to have slight value as food plants, though their close relatives, the water liverworts (*Ricciocarpus natans* and *Riccia fluitans*), furnish green food available to waterfowl. *Marchantia polymorpha*, a soil-building liverwort, is found in the fen vegetation around climax prairie springs ("bogs") (Fig. 38).

However, water mosses shelter myriads of minute water fauna. Mosses are conservers of soil, which is held in place by their rhizoids and protonema. As the mosses die, humus of the soil is increased by their decomposition products. Since common mosses which grow in the soil can hold eight to ten times their weight in water, as shown by the work of Picciol (1919), they help to conserve the runoff from rains and release

it slowly to the air. In this manner they reduce erosion. Mosses in swamps and bogs assist in the formation of peat, a product with high water-holding capacity.

Runoff from moss-covered soil has no turbidity. Clear water is favorable to the production of aquatic seed plants. Moss-covered soil helps to reduce turbidity and should therefore be protected, insofar as it is the chief or only cover of many exposed areas such as roadside banks. Mosses may also be regarded as pioneers, or forerunners of more specialized plants which have root systems.

If one would recognize the mosses at work in the community, he might begin by looking along a newly graded highway, on eroding roadside banks, damp garden paths, areas in a pasture where the grass has been injured, or on barren hilltops. On this uncovered, unstirred soil, creep green moss threads which later grow into a low, cushion-like plant with leaflike, stemlike, rootlike structures. Among these green mats on roadside banks may be found *Ceratodon purpureus* which also grows on burnt-over places, rocks, old roofs, and sandy shores. *Barbula unguiculata* and *Funaria hygrometrica* are among the pioneers seen upon roadside banks. Other pioneering soil-holding mosses of open country include species of *Weisia*, *Atrichum* (Catharinea), *Bryum argenteum* (silvery bryum), and *Bryum caespitium* (tufted bryum).

Mosses which cover hard paths, or occur in barren fields or sometimes along lake beaches include *Physcomitrium turbinatum* (the urn moss), *Bryum caespitium*, *Bryum argenteum*, and species of *Atrichum* (Catharinea). *Orthotrichum*, as well as *Weisia*, grows in dark patches on rocks and trees of orchards or about houses, and in open woods. *Platygyrium repens*, *Lindbergia* and species of *Leskea* commonly grow on the bark of trees. *Grimmia* grows in black patches on rocks. *Tortula* (twisted moss) is found upon rocks and walls. *Frullania eboraensis*, a mosslike, scale-leaved liverwort, traces embroidery-like designs on the stems of trees. The *Polytrichums* (hair-cap mosses) carpet old fields and hilltops (Fig. 37). The hair-cap grows on thin soil of rocks in Gitche Manito State Park.

Among the mosses which anchor the soil slipping off from springy hillsides are *Thuidium* (fern moss) and *Climacium* (tree moss). These occur either in woods or open fields. Woodland banks and slopes are stabilized by *Anomodon attenuatus*, *A. minor*, *A. rostratus*, *Timmia megapolitana*, *Mnium affine*, and *M. cuspidatum*. Among the mosses which help to reduce the bark of dead trees to elementary soil constituents are *Entodon seductrix* and *E. compressus*. Mosses found in running spring water and in stagnant water nearly all belong to the *Hypnum* family. Among these are the species of *Drepanocladus* and *Campylium*. Taylor (1920) showed that mosses are among the highly important pioneer plants on bare rock surfaces and continue through plant successions far into the forest association.

Conard (1935) classified mosses with reference to soil-holding properties as inhabitants of (1) aggrading areas and (2) degrading areas. He



states, "Aggrading mosses are able to grow upward as fast as the soil is washed in around them, up to a limit. . . . Notable aggrading mosses are *Atrichum* (*Catharinea*) *angustata*, *Polytrichum commune*, *Bryum caespitium*, *Ceratodon purpureus*, *Amblystegium riparium*, and *A. irriguum*. *Brachythecia* of the *salebrosum* group can creep out of a shallow covering of soil." This ability is possessed by *Brachythecium acutum* and *B. oxycladon*. "Degrading mosses quickly succumb to a covering of earth. Steep banks where degradational processes predominate are peopled by *Anomodon*, *Bartramia*, *Thuidium* and *Hypnum*. In general, the erect growth of *Acrocarps* is favorable on aggrading surfaces, and creeping mats of *Pleurocarps* are suitable to degrading surfaces. In both cases, the soil movement is arrested, in the first by catching and holding the downwash, in the second by preventing soil movement."

Mosses, then, are of economic importance, as soil formers, through their ability to decompose rock and to enrich the soil with organic material derived from generations of their bodies; in the conservation of soil, through their ability to check erosion of clay and sand surfaces, to hold soil on the floodplain as it is washed in, and to arrest the formation of gullies in their early stages; in the local conservation of rainfall through their ability to absorb water and give it up slowly. Because of their ability to conserve water and to check runoff, they help to prevent floods.

Persons concerned with conservation of natural resources may well protect these myriads of plant assistants. Conard states "unfortunately all moss mats on soils are easily broken by trampling of people and domestic animals. Consequently in State Parks and preserves, visitors should keep and be kept strictly on prepared paths, wherever damage to ground cover is likely. Livestock must be kept out of hilly forest and erosion control projects."

#### THE ALGAL FLORA

Algal studies have been made to determine the species present, to discover their influence upon the growth of aquatic seed plants, and to note how algae may be useful as service plants to waterfowl.

The algae systematically arranged under the head of *Thallus* Plants in the following list may be referred to inclusively as groups with reference to their biologic roles. Bodies of water, in which animal and plant life are relatively balanced, have a considerable growth of grass-green algae (*Chlorophyceae*). The members of the *Volvox* family are conspicuous in ponds, quiet bays, and clear water of mountain lakes. They also appear in pools after rains. The *Chlorophyceae* are found especially in grassy pools which have no turbidity. The washing in of silt, in Iowa lakes in the past fifty years since the natural cover has been removed from the soil, must have greatly increased their turbidity. Early accounts of the state written by John Plumbe (1839) and reprinted in the *Annals of Iowa* (1925) refer to the crystal clearness of the streams. That silt deposits in the lakes average a depth of more than 10 feet and reach a maximum of more than 30 feet was discovered in the meandered stream

survey conducted by the Board of Conservation and the Iowa State Planning Board and recorded in the *Second Report* of the Iowa State Planning Board.

The filamentous grass-green algae whose families are respectively named for the genera *Ulothrix*, *Chaetophora*, *Oedogonium* and *Zygnema* appear periodically in fresh, clear water of ponds, roadside ditches, streams, and unpolluted lakes. Some algae are spring annuals, others summer or fall annuals. They soon pass through their life cycles and become invisible in the form of resting cells which sink, and the conspicuous plant bodies are replaced by other seasonal forms. These species of grass-green and yellow-green algae furnish food for tadpoles, crustaceae, and larvae, which in turn furnish food for fish or for certain waterfowl.

Among the grass-greens is a group, the *Cladophora* Family, which include coarse, more or less branched species. The *Cladophoras* often serve as food for animals though some species with their allies, *Pithophora* and *Rhizoclonium*, constitute blanket algae which cover acres of shallow lakes with their tangled threads. This blanket shades submerged seed plants such as *Potamogetons*, *Zannichellia*, and other aquatic seed plants. In this respect blanket algae are harmful. They may also reduce the oxygen supply in fish ponds during the night, causing the death of young fishes. They, however, furnish shade from the sun, available to mature fish and other water fauna.

Representatives of the class of algae known as blue-greens (*Myxophyceae* or *Cyanophyceae*) often produce unfavorable manifestations when they occur in great numbers. They are significant as indicators of water conditions, for their presence shows that the water in which they grow is contaminated by the presence of decaying organic matter. According to Tilden (1935), the source of the organic matter may come from swamps; forest or grass fires; decomposition products or dead vegetable matter of any kind, such as leaves, or aquatic plants; and waste from factories and human habitation. Variations in water level, especially lowering of the level, have a marked influence on the growth of algae. The conspicuous presence of blue-green algae indicates that water is polluted with an excess of organic matter. Their presence also signifies that such organic matter is being reduced to a more rudimentary state such as nitrates which are unsynthesized materials essential to living plants. However, when this process takes place on too large a scale for the volume of water present, the by-products are offensive to the senses. Blue-green algae under normal conditions are ordinarily invisible to the average observer; but under favorable environmental conditions involving waters overloaded with organic matter and characterized by relatively high temperatures prevailing in shallow bodies of water, the algae increase so rapidly that the water becomes bluish-green in color and in consistency resembles pea soup. This phenomenon is known as "water bloom." In this state the water has an unpleasant odor and taste, also a toxic effect upon animals which drink it. When water is not overloaded with organic

materials so that the various species of algae have a normal distribution, blue-green algae of the free-floating plankton type are regarded as a valuable constituent of food of fish and other forms of faunal life.

All members of the Chara family are used as food by waterfowl.

The annotated list of algae shows that the plankton, or free-floating species of algae occurring in Virgin Lake, include more species than are found in the plankton of Lost Island Lake. The distribution of species seems balanced, and the increase of any group to the extent of forming "wasserblute" has not been noted in Virgin Lake. However, in Lost Island Lake three species, *Microcystis flos-aquae*, *M. aeruginosa*, and *Aphanizomenon flos-aquae* become abundant as early as May, reaching a peak in July and August, when their decomposition products become noxious to shore inhabitants and appear to interfere with the growth of water flora and fauna.

The epiphytic blue-greens such as *Gleotrichia* and the blanket types such as *Anabaena*, *Lyngbya*, and *Phormidium* become abundant in Round Lake Preserve and in Mud Lake when the water level becomes too low to support the growth of seed plants which thrived during higher water levels.

The grass-green algae functioning as blankets include the coarse types such as *Rhizoclonium* and *Pithophora* which frequent stagnant waters and persist for a longer period of the summer (two or three months) than do the filamentous forms of the *Zygnemaceae* such as *Spirogyra*, *Zygnema* and *Mougeotia*. The latter are most frequent in well-aerated fresh water near the inflow of springs, or at the inlets of lakes. This condition is notable at the inlet of Lost Island Lake. The species of this type of filamentous green-algae succeed each other as spring, summer, and fall annuals. When the water level is normal they appear to furnish little material subject to putrefaction. If a quantity of this material is caught by a rapidly reduced water supply they sometimes become malodorous, because of disintegrating processes induced by bacterial action. However, their bodies may also dry without manifestation of gaseous decomposition. By normal reproductive processes, their protoplasm becomes encased in capsular walls and goes into a resting stage, and mostly cellulose cell walls remain. When unfavorable conditions prevail, relative to the supply of organic and inorganic materials which the water can carry, the vegetative bodies of algae may die without encasing their protoplasts in resting stage. Bacterial action may reduce the organic compounds rapidly with resultant disagreeable odors. Certain species of blue-green algae appear as epiphytes on the decadent filaments of green-algae and seem to function, eventually, as saprophytes, thus bringing about a succession of species as well as reducing organic matter to simpler states in which it may pass through the cycle of living bodies.

## SUMMARY

The territory of Clay and Palo Alto Counties constitutes a floristically unsurveyed section of the Wisconsin Drift Lake District. The flora of the other two counties of this topographic unit has a considerable literature. Attention was first directed to the Ruthven Area as a center of wildlife investigation in which are located most of the state-owned preserves and wildlife refuges.

The climate of the two counties is characteristic of the northwestern eighth of the state, which may be described as grassland climate. This section is colder in winter, and drier in summer; and though not hotter than the rest of the state, the low precipitation-evaporation ratio constitutes a critical factor which limits the growth of such vegetative types as forest.

Early historic records concerning impressions of the flora show that the streams and lakes were clear and little silted; that the vegetation was luxuriant, and impressive from an aesthetic viewpoint.

The topography of the area was shaped in the last glacial epoch and includes both early and late Wisconsin drifts. Its aspect is that of a highland region in the vicinity of the Altamont Moraine, the divide which diverts the runoff on the east into the Mississippi River and on the west into the Missouri. Shallow lakes, kettleholes, swamps, intermittent streams, and ponds are indicative of the relatively undeveloped drainage of the morainal region, but the plains country on either side is comparatively well drained by the somewhat immature river systems of the Des Moines and the Little Sioux. The soils are of glacial origin and include upland, alluvial and undifferentiated peat. They are climatically described as prairyerths.

The natural vegetation belongs to the true-prairie association of the climax grassland formation. Its developmental history is chiefly of hydrosere origin. Though the native prairie is quite generally destroyed, some areas of natural vegetation yet remain in the state-owned refuges, preserves, and elsewhere.

Preserves of natural vegetation are shown to be useful as historical records of the primeval aspect of the state; as living records of its flora and fauna in their natural environment; as examples of natural topographic and vegetative composition, typical of the climate of the region; and as field laboratories, where plants may be studied with reference to their economic and biological significance.

The flora reported in a six-year survey of Clay and Palo Alto Counties include 943 species consisting of 818 seed plants, 9 ferns, and 62 mosses and 54 algae. Of these, 204 species of seed plants were introduced from outside of North America. The chief floras which are represented in the true prairie climax grassland include the invading northern broad-leaved forest, the eastern broad-leaved forest, the plains flora, and the relict northern "bog" (fen) floras.

The plants listed have significance to waterfowl, selectively as the

source of food materials and nest construction; collectively as cover; and in the sense of vegetations and floras as indicators of life zones.

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## THE ANNOTATED LIST OF PLANTS

### *Source of Records*

The specimens on which the following list is based have been filed in the herbarium of Iowa State College. The greater number were collected by the writer during the years of 1933-1941. The herbaria of the University of Iowa and of Grinnell College were consulted for supplementary material. Reference to the occurrence or relative distribution of specimens is made by citing the collection number of the writer in parenthesis, when the abundance of the plant is not known, or if the plant is of particular interest because of its rarity, or its probable service to waterfowl. If the plant occurs in every township, or is generally distributed, the collection number is not cited. Where the county is not mentioned, it is understood that the range includes both counties. The map of the Ruthven Area (Fig. 1) shows the location of the chief aquatic collecting stations. County maps showing townships, rivers, and lakes not included in Figure 1, are available from offices of the County Engineers at Spencer and Emmetsburg. A free road map of Iowa, distributed by the State Highway Commission, Ames, Iowa, supplies perspective on the relative location of lakes, rivers and political boundaries.

Identifications of plants were made by the use of various manuals, monographs and floras listed in literature. The names are based on the seventh edition of Gray's Manual, supplemented by revisions and corrections embodied in subsequent literature, which is cited in the text. Hitchcock's Manual of the Grasses of the United States was chiefly used for Gramineae. The International code of nomenclature is followed.

In the determination or verification of critical species, assistance was received from Dr. C. R. Ball, *Salix*; Dr. S. F. Blake, the *Multiflorus* group of *Asters*; Dr. Robert Clausen, *Najas*; Dr. H. S. Conard, *Bryophyta*; Mrs. Agnes Chase, *Gramineae*; Dr. C. O. Erlanson, *Viola*; Dr. M. L. Fernald, *Narrow-leaved Potamogeton*; Dr. F. J. Herman, *Carex*; Dr. Rogers McVaugh, *Lobelia*; Mr. E. T. Palmer, *Crataegus* and other woody species; Dr. F. W. Pennell, *Scrophulariaceae*; Mr. C. A. Weatherby and Dr. Lyman B. Smith, miscellaneous; Dr. H. K. Svenson, *Eleocharis*; Dr. K. M. Wiegand, *Asters of the Paniculatus group*.

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Div. THALLOPHYTA  
(Thallus plants)Subdiv. SCHIZOPHYTA  
(Fission plants)Class MYXOPHYCEAE or CYANOPHYCEAE  
(Blue-green Algae)Ord. CHROOCOCCALES  
(Solitary, colonial, Blue-green algae)

## CHROOCOCCACEAE (Chroococcus Family)

*Aphanocapsa delicatissima* W. and G. S. West

With plankton in Virgin Lake, Palo Alto Co. May.

*Aphanocapsa grevillea* (Hass.) Rab.

Growing in meshes of *Rhizoclonium* associated with *Anabaena cyadeae* and *Entoderma pithophora* in Round Lake, Clay Co. August. Virgin Lake, Palo Alto Co. May.

*Microcystis aeruginosa* Kütz.

Occurring in "water bloom" association with *Microcystis flos-aquae* (Wittr.) Kirchn. in Lost Island Lake, Clay and Palo Alto Counties. July and May. Noticeable from May to October but especially conspicuous in July and August.

*Microcystis flos-aquae* (Wittr.) Kirchn.

Common in "water bloom" associated with *M. aeruginosa* in Lost Island Lake, Clay and Palo Alto Counties. May and July. Present throughout the year, either floating in the warm months, or on the floor of the lake in cool months.

*Merismopedia tenuissima* Lemm.

Associated with plankton in Virgin Lake, Palo Alto County. May.

*Aphanothece clathrata* W. and G. S. West

With plankton in Virgin Lake, Palo Alto County. May.

Ord. HORMOGONALES  
(Filamentous blue-greens)Subord. HOMOCYSTINEAE  
(Uniseriate, filamentous blue-greens)

## OSCILLATORIACEAE (Oscillatoria Family)

*Oscillatoria sancta* Kütz.

Among filamentous green algae from Round Lake, Clay Co. May.

*Oscillatoria splendida* Grev.

Mixed with *Anabaena californica* Borge on stems of *Ceratophyllum*, north of bay Trumbull Lake, Clay County. August.

*Phormidium inundatum* Kütz.

Forming a coating on wood in a flowing spring and occurring on the ground around its mouth, Sec. 30, Lost Island Twp., Palo Alto Co. August.

*Phormidium retzii* (Agardh.) Gomont

Growing in felt-like mats on submerged aquatic seed plants. Trumbull Lake, Clay County. August.

*Lyngbya contorta* Lemm.

Occurring with plankton including *Aphanocapsa*, *Aphanothece*, and *Microcystis* in Virgin Lake, Clay County. May.

*Lyngbya lagerheimii* (Mob.) Gom.

Forming a flocculent light green mass on stems of submerged seed plants and including suspended in its meshes, many diatoms. Lost Island Lake Bridge, Clay County. August.



*Lyngbya major* Meneghini

Intermingled with green algae around stems of aquatic seed plants in Mud Lake, Clay County. September.

*Spirulina major* Kütz.

With plankton in Virgin Lake. August.

Subord. HETEROCYSTINEAE  
(Multiseriate, filamentous blue-greens)

## NOSTOCACEAE (Nostoc Family)

*Anabaena californica* Borge

Forming mats around green algae and around stems of aquatic seed plants in Trumbull Lake, Clay County. August.

*Anabaena cycadeae* Reinke

*Nostoc punctiforme* (Kütz.) Harriot

Growing on fruiting *Rhizoclonium* and in mats on other filamentous algae in Round Lake, Clay County. August.

*Anabaena hallensis* (Jancz.) Born. and Flah.

Intermingled with fruiting *Rhizoclonium* and other filamentous algae in Trumbull Lake, Clay County. August.

*Aphanizomenon flos aquae* (L.) Ralfs

Abundant in Lost Island Lake. Associated with *Microcystis aeruginosa* and *Anabaena flos-aquae*. May to September.

*Nostoc commune* Vaucher

Attached to filamentous algae in shallow water around the border of lakes.

## RIVULARIACEAE (Rivularia Family)

*Coeleosphaerium kützingianum* Nägeli

Not abundant. Associated with *Gloeotrichia echinulata* in September.

*Gloeotrichia echinulata* (J. E. Smith) P. Richter

Plankton in Lost Island Lake in August and September.

*Gloeotrichia natans* (Hedw.) Rabenhorst

Epiphytic on the stems of submerged seed plants in Round Lake, Clay County. Abundant. September.

*Gloeotrichia pisum* (Agardh) Thuret

Attached to the stems of water plants in Round Lake, Clay Co., and Mud Lake, Palo Alto Co.

*Rivularia compacta* Collins

Attached to stems of Potamogeton in Round Lake, Clay County. Common. August.

Class HETEROKONTAE  
(Yellow-green algae)

## TRIBONEMATACEAE (Tribonema Family)

*Tribonema bombycinum* (Agardh) D. and S.

Frequent in spring in roadside ditches and grassy marshes. Clay and Palo Alto Counties. May.

*Tribonema minus* (Wolle) Hazen

Common with other filamentous algae in roadside ditches Clay and Palo Alto Counties. May.

Div. CHLOROPHYTA  
(Yellow-green algae)

Class CHLOROPHYCEAE  
(Grass-green algae)

Ord. VOLVOCALES  
(Free-swimming, colonial, green algae)

VOLVOACEAE (Volvox Family)

*Eudorina elegans* Ehr.

Small pools, borders of lakes and ponds in quiet water, Clay and Palo Alto Counties. May and August.

*Pleodorina californica* Shaw

Roadside ditches, ponds or quiet bays of lakes, Clay and Palo Alto Counties. May and August.

Ord. TETRASPORALES  
(Non-motile, colonial, green algae)

PALMELLACEAE (Palmella Family)

*Gloeocystis gigas* (Kütz.) Lagerheim

Among filaments of *Oedogonium*, *Spirogyra* and *Geminella* at the Inlet of Lost Island Lake, Palo Alto County. May.

Ord. ULOTRICALES  
(Uninucleate, uniseriate, filamentous green algae)

ULOTRICACEAE (Ulothrix Family)

*Geminella minor* (Nägeli) Heering

Among filamentous algae, Inlet of Lost Island Lake, Clay Co. May.

*Ulothrix zonata* (Webb. and Mehr.) Kütz.

In grassy pools, swamps and sloughs, with filamentous algae. May and June.

CYLINDROCAPSACEAE (Cylindrocapsa Family)

*Cylindrocapsa geminella* Wolle

Pond in Dewey's Pasture. North bay of Virgin Lake.

*Microthamnion keutzingianum* Nägeli

Attached to the stems of submerged aquatic plants. Mud Lake. Round Lake. Trumbull Lake.

CHAETOPHORACEAE (Chaetophora Family)

*Chaetophora elegans* (Roth) Agardh

Attached to stems in the cold, running water of a spring in Logan Twp., Clay Co.; in a similar habitat in a spring east of Lost Island Lake.

*Draparnaldia glomerata* (Vauch.) Agardh

Pools, grassy ponds and borders of lakes, Clay and Palo Alto Counties. April and May.

*Entocladia pithophorae* (G. S. West) Smith

*Endoderma pithophorae* G. S. West

Common on filaments of *Pithophora*, *Rhizoclonium*, *Cladophora* and stems of submerged water plants in the lakes of Clay and Palo Alto Counties. July and August.

*Microthamnion keutzingianum* Nägeli

Attached to the stems of submerged aquatic plants. Mud Lake. Round Lake. Trumbull Lake.

*Stigeoclonium lubricum* Kütz. var. *varians* (Hazen) Collins

*Myxoxonema lubricum* var. *varians* Hazen

Attached to stones on the wave washed shore of Lost Island Lake, Clay and Palo Alto Counties. May.

#### Ord. CLADOPHORINEAE

(Multicellular, filamentous green algae with multinucleate cells)

#### CLADOPHORACEAE (Cladophora Family)

*Cladophora canalicularis* (Roth.) Kütz.

Attached to stones on the wave beaten beaches of lost Island Lake in Clay and Palo Alto Counties. May.

*Cladophora crispata* (Roth.) Kütz. forma *vitrea* (Kütz.) Rab.

Forming loose masses among stems of submerged water plants in Round Lake, Clay County. May.

*Cladophora glomerata* (L.) Kütz.

Anchored on rocks along the southwest shore of Lost Island Lake in Clay and Palo Alto Counties. May and October.

*Pithophora varia* Wille

In lakes of Clay and Palo Alto Counties. Fruiting in Trumbull Lake in August. Forms blankets over submerged plants in early summer.

*Rhizoclonium crispum* Kütz.

Occurring in lakes of Clay and Palo Alto Counties throughout the year. Floating in mats. June to July.

*Rhizoclonium hieroglyphicum* (Ag.) Kütz.

Occurring in the lakes of Clay and Palo Alto Counties throughout the year. Forming blanket-like mats which shade submerged plants in early summer. A copious growth was noted on the shell of a snapping turtle in Round Lake. May.

*Rhizoclonium hookeri* Kütz.

Forming mats on the surface of lakes and sloughs in Clay and Palo Alto Counties throughout the year. In May, 1941, a copious cushion of this species was noted on the bank of Pickerel Run from which issued a flowing spring. Grows actively in early summer and fruits during July and August.

#### SPHAEROPLEACEAE (Sphaeroplea Family)

*Sphaeroplea annulina* (Roth.) Ag.

In Round Lake with filamentous algae.

#### Ord. SIPHONALES

(Siphon-like green algae, with multinucleate cell and multiciliate zoospores)

#### VAUCHERIAACEAE (Vaucheria Family)

*Vaucheria* DC.

The following species are reported for this section of Iowa in Dickinson County<sup>4</sup>:

*Vaucheria geminata* (Vauch.) DC., *V. longipes* Collins, *V. orthocarpa* Reinsch, and *V. sessilis* (Vauch.) DC.

<sup>4</sup> Collections of algae made periodically during 5 years appear to have disappeared from their place of storage. Since the periodicity of algal occurrence requires collection to be made at intervals in order to secure fruiting stages, it was impossible to replace the material needed for study of the group of filamentous forms. For this reason, the records of Prescott and Tiffany from Dickinson County are cited to show what species have been reported from a territory thirty miles distant.

#### Ord. OEDOGONIALES

(Filamentous, uninucleate green algae with multiciliated zoospores)

## OEDOGONIACEAE (Oedogonium Family)

*Bulbochaete* Agardh

According to Tiffany (1926) and Prescott (1931) the following species of *Bulbochaete* are found in Dickinson County which is adjacent to Clay and Palo Alto Counties. *Bulbochaete conjener* Hirn, *B. gigantea* Pringsheim, *B. intermedia* Debary, *B. minor* A. Braun, and *B. varians* Wittr.

*Oedogonium supremum* Tiffany

Occurring in ponds and shallow pools. Clay and Palo Alto Counties. May.

The records of Tiffany (1926) and Prescott (1931) list the following species for this region: *Oedogonium acrosporum* DeBary, *Oe. anomalum* Hirn, *Oe. aerolatum* Lagerheim, *Oe. bohemicum* Hirn, *Oe. borisianum* (Le Cl.) Wittr., *Oe. boscii* (Le Cl.) Wittr., *Oe. braunii* Kützing, *O. capilliforme* Kützing, *Oe. cardiacum* (Hass.) Wittr., *Oe. ciliatum* (Hass.) Pringsheim, *Oe. concatenatum* (Hass.) Wittr., *Oe. crassiusculum* Wittr. var. a *idioandrosporum* Nordst. and Wittr., *O. crassum* (Hass.) Wittr., *Oe. crenulato-costatum* Wittr., *Oe. crispum* (Hass.) Wittr., *Oe. cyathigerum* Wittr., *Oe. decipiens* Wittr., *Oe. dictyosporum* Wittr., *Oe. exocostatum* Tiffany, *Oe. exosporale* Tiffany, *Oe. flavescens* (Hass.) Wittr., *Oe. fonticola* A. Braun, *Oe. fragile* Wittr., *Oe. franklinianum* Wittr., *Oe. globosum* Nordstedt, *Oe. gracillimum* Wittr. and Lund, *Oe. grande* Kütz., *Oe. hirmii* Gutw., *Oe. hystricinum* Transeau and Tiffany, *Oe. infimum* Tiffany, *Oe. inversum* Wittr., *Oe. iowense* Tiffany, *Oe. landsboroughii* (Hass.) Wittr., *Oe. latiusculum* Tiffany, *Oe. longatum* Kütz., *Oe. macrandium* Wittr., *Oe. macrospermum* West and West, *O. nanum* Wittr., *O. oblongum* Wittr., *O. oviforme* (Lewis) Hirn, *Oe. paucocostatum* Transeau, *Oe. pisanum* Wittr., *Oe. plagiostomum* Wittr., *Oe. pratense* Transeau, *Oe. praticolum* Transeau, *Oe. pringsheimii* Cram., Wittr. *Oe. pusillum* Kirchner, *Oe. rufescens* Wittr., *Oe. rugulosum* Nordstedt, *O. suecicum* Wittr., *Oe. supremum* Tiffany, *Oe. tyrolicum* Wittr., *Oe. varians* Wittr. and Lund, *Oe. vaucherii* (Le Cl.) A. Braun; Wittr., *Oe. welwitschii* West, *Oe. wyllei* Tiffany.

Ord. ZYGNEMATALES  
(Conjugating filamentous algae)

## ZYGNEMACEAE (Zygnema Family)

*Debarya* Wittr.

*Debarya decussata* Transeau is recorded for Dickinson County.

*Mougeotia* Agardh

The following are reported for Dickinson County: *Mougeotia elegantula* Wittr., *M. genuflexa* (Dillw.) Agardh, *M. nummuloides* (Hass.) DeToni, *M. robusta* (DeBary) Wittr., *M. scalaris* Hassal, *M. sphaerocarpa* Wolle, *M. tenuis* (Cleve.) Wittr.

*Spirogyra porticalis* (Müller) Cleve.

Generally distributed in lakes of Clay and Palo Alto Counties. Fruiting in May.

*Spirogyra tenuissima* (Hass.) Kütz.

Abundant in Inlet of Lost Island Lake. Recurrent in lakes, ponds and pools. May.

The following occur in Dickinson County according to Prescott (1931) and Tiffany (1926): *Spirogyra angolensis* Welwitsch, *S. borgeana* Tran., *S. borysthenica* Kasau and Smirn., *S. braziliensis* (Nordstedt) Transeau, *S. catenaeformis* (Hass.) Kütz., *S. circumlineata* Transeau, *S. crassa* Kütz., *S. daedalea* Lagerheim, *S. decimina* (Müller) Kütz., *S. fluviatilis* Hilse, *S. hylina* Cleve., *S. jüergensii* Kütz., *S. laxa* Kütz., *S. longata* (Vauch.) Kütz., *S. majuscula* Kütz., *S. maxima* (Hass.) Wittr., *S. nitida* (Dillw.) Link, *S. novae-angliae* Trans., *S. pratensis* Trans., *S. protecta* Wood, *S. quadrata* (Hass.) Petit, *S. reticulata* Nord., *S. spreeiana* Rab. *S. stictica* (Eng. Bot.) Wille, *S. subreticulata* Fritsch, *S. varians* (Hass.) Kütz.

*Zygnema* Agardh

For Dickinson County are recorded: *Zygnema cruciatum* (Vauch.) Agardh, *Z. pectinatum* (Vauch.) Agardh, and *Z. stellinum* (Müller) Agardh.

Div. CHAROPHYTA  
(Characeous Plants)

CHARACEAE (Chara Family)  
Sub-Fam. NITELLEAE

*Nitella opaca* Agardh

Occurring in Round, Trumbull, Mud and Virgin Lakes in Dan Green Slough and in Ponds in Dewey's Pasture. May and September.

*Tolypella glomerata* Leonhard

Round Lake, Clay County, Fruiting in August.

## Sub-Fam. CHAREAE

*Chara braunii* Gmel.

Lakes and sloughs, Clay and Palo Alto Counties.

*Chara contraria* A. Braun

Lakes and swamps, Clay and Palo Alto Counties.

*Chara fragilis* Desvaux

Ponds and sloughs, Clay and Palo Alto Counties.

*Chara vulgaris* L.

*C. foetida* A. Br.

Recurrent in hanging bogs, Clay and Palo Alto Counties.

Div. BRYOPHYTA  
(Liverworts and Mosses)

Class HEPATICAE  
(Liverworts)

## FRULLANIACEAE (Scale-leaved Liverwort Family)

*Frullania eboracensis* Gotts.

Ann. Bry. 10:3-8, 1938.

H.S. Conard, occurring on bark, Clay Co.

*Frullania inflata* L. and L.

Two miles southeast of Spencer, H.S. Conard, Clay Co. Three miles southwest of Emmetsburg, H.S. Conard, Palo Alto Co.

## MARCHANTIACEAE (Leafy Liverwort Family)

*Conocephalum conicum* (L.) Dum.

Conocephalum

On a damp soil and on roots of trees bordering a woodland spring along the Des River one and one-half miles west of Osgood (7,556), Palo Alto Co.

*Mannia fragrans* (Balbis) Frye and Clark

Fragrant Mannia

On gravelly soil, in spaces not covered by grass.

*Marchantia polymorpha* L.

Marchantia

Wet soil around a prairie spring five miles east of Ruthven, Palo Alto Co.

## RICCIACEAE (Water Liverwort Family)

*Ricciocarpus natans* (L.) Corda

Purple-Fringed Riccia

Ann. Bry. 10:2-8, 1938.

*Riccia natans* L.

Frequent in clear reedy water of ponds and sloughs; also on moist earth.

*Riccia beyrichiana* Hampe

Beyrich's Riccia

On bare soil of furrows at the edge of a low meadow bordering a cornfield. Five miles north of Lost Island Lake (7,557), Palo Alto Co.

*Riccia fluitans* L.

Slender Riccia

Frequent in clear water of ponds and sloughs.

*Riccia frostii* Austin

Three miles west of Emmetsburg at the intersection of Highways 17 and 18. Growing on moist soil bordering a recently dried pond filled with *Scirpus validus*, in a cornfield. Associated with *Riccia carpus natans* (7,565), Palo Alto Co.

## ANTHOCEROTACEAE (Anthoceros Family)

*Anthoceros punctatus* L.

Dotted Anthoceros

On damp soil in a fallow oat field five miles north of Lost Island Lake. Associated with *Notothylas orbicularis* (7,563), Palo Alto Co.

*Notothylas orbicularis* (Schwein.) Sull.

Notothylas

On damp soil in a fallow oat field five miles north of Lost Island Lake (7,563), Palo Alto Co.

## Class MUSCI

(Mosses)

## POLYTRICHACEAE (Polytrichum Family)

*Atrichum angustatum* (Brid.) Bry. Eur.

Atrichum

See Moss Flora of N.A. 1:100, 1936. The Bryologist 43:117, 1941.

*Catharinea angustata* Brid.

Dry hillside, Wanata State Park, one mile south of Peterson (9,699), Clay Co.

## DITRICHACEAE (Ditrichum Family)

*Ceratodon purpureus* (Hedw.) Brid.

Ceratodon

Shaded woodland slope one mile west of Gillett Grove (9,713), Clay Co. Frequent on eroding banks.

## POTTIACEAE (Pottia Family)

*Barbula unguiculata* Hedw.

Common Barbula

Two miles southeast of Spencer, H.S. Conard, Clay Co.

*Tortula mucronifolia* Schw.

Twisted Moss

On well-curb at farm west of Spencer, H.S. Conard, Clay Co.

## FUNARIACEAE (Funaria Family)

*Funaria hygrometrica* Hedw.

Cord Moss

Bordering a spring along the margin of Pickerel Run at the southeast entrance to Dickens along Highway 18 (9,708), Clay Co.

*Physcomitrium turbinatum* (Michx.) Brid.

Urn Moss

Border of a spring along Pickerel Run at the southeast entrance to Dickens, on Highway 18 (9,710), Clay Co. Around a bog one and one-half miles west of Osgood (9,965), Palo Alto Co.

## ORTHOTRICHACEAE (Orthotrichum Family)

*Orthotrichum pumilum* Dicks.

Dwarf Orthotrichum

See Moss Flora of N. A. 2:128, 1935.

*O. schimperi* Hamm.

Three miles southwest of Emmetsburg, H. S. Conard, Palo Alto Co.

## TIMMIACEAE (Timmia Family)

*Timmia megapolitana* Hedw.

Timmia

Moist soil, wooded slopes along the Little Sioux River, one mile south of Peterson (9,702), Clay Co. In a hanging bog, woodland along the Des Moines River, one and one-half miles west of Osgood (9,968 and 9,969), Palo Alto Co.

## BRYACEAE (Bryum Family)

*Bryum argenteum* (L.) Hedw.

Silvery Bryum

On wooden well curb at farm west of Spencer, H.S. Conard, Clay Co.



- Bryum caespitium* (L.) Hedw. Common Bryum  
H. S. Conard, Clay Co.
- Bryum cuspidatum* (Bry. Eur.) Schimp. Cusp-leaved Bryum  
*B. affine* Lindb.  
Around a spring bordering Pickerel Run at the entrance to Dickens, along Highway 18 (9,706); moist hillside one mile west of Gillett Grove (9,691), Clay Co.
- Leptobryum pyriforme* (Hedw.) Schimp. Long-necked Bryum  
In rotted cavity of a tree, Emmetsburg, Hubert Pye, Palo Alto Co.
- MNIACEAE (Mnium Family)
- Mnium affine* Bland Toothed Mnium  
Moist wooded slope, one mile west of Gillett Grove (9,726), Clay Co.
- Mnium cuspidatum* Hedw. Woodsy Mnium  
Moist, shady hillsides along the Little Sioux River, Wanata State Park (1,057 and 9,700), Clay Co. Bark of a tree one and one-half miles west of Osgood along the Des Moines River (9,725 and 9,726), Palo Alto Co.
- HYPNACEAE (Hypnum Family)
- Amblystegium varium* (Hedw.) Lindb. Variable A. or Feather Moss  
Wet soil along the south shore of Lost Island Lake (9,723); three miles southwest of Emmetsburg, H. S. Conard, Palo Alto Co.
- Brachythecium acutum* (Mitt.) Sull. Sharp-leaved B. or Feather Moss  
H. S. Conard, Clay Co.
- Brachythecium oxycladon* (Brid.) J. and G. Long-capsuled B. or Feather Moss  
Two miles northeast of Spencer, H. S. Conard; two miles southeast of Spencer, H. S. Conard, Clay Co., one and one-half miles west of Osgood in a hanging bog along the west side of the Des Moines River (9,972), Palo Alto Co.
- Brachythecium rutabulum* (Hedw.) Bry. Eur. Rough-stalked B. or Feather Moss  
See Bryologist 43:126, 1940.  
Moist woodland, one mile west of Gillett Grove (9,694), Clay Co.
- Bryhnia graminicolor* (Brid.) Grout Grass-colored B. or Feather Moss  
Moist soil along the Little Sioux River in Wanata State Park at Peterson (9,702), Clay Co.
- Campylium hispidulum* (Brid.) Mitt. Bristly C. or Feather Moss  
See Moss Flora of N. A. 3:78, 1931.  
*Hypnum hispidulum* (Brid.) Mitt.  
Wet, low woods along the Little Sioux River in Wanata State Park, Peterson (9,720 and 9,698), Clay Co.
- Campylium stellatum* (Hedw.) Lange and C. Jens. var. *protensum* (Brid.) Rohl. H. *protensum* Brid. Creeping C. or Feather Moss  
Swampy area around prairie spring, on knolls (1,063 and 9,966), Palo Alto Co.
- Chamberlainia acuminata* (Hedw.) Grout Erect Feather Moss  
See Moss Flora of N.A. 3:27, 1928.  
*Brachythecium acuminatum* (Hedw.) Kindb.  
On bark of a tree, along slopes of hills bordering the Little Sioux River, at Gillett Grove (1,064), Clay Co. On trees along the south bank of Rush Lake (9,729), Palo Alto Co.
- Drepanocladus aduncus* (Hedw.) Warnst. Swamp D. or Sicklebranch Moss  
Springy ground on the trunk of a willow at the entrance to Dickens along Pickerel Run, near Highway 18 (9,705b); moist woodland one mile west of Gillett Grove (9,616 and 9,692), Clay Co.
- Drepanocladus aduncus* (Hedw.) Warnst. var. *intermedius* (Lindb.) Warnst. Swamp D.  
Margin of a spring bordering Pickerel Run at entrance to Dickens (9,711); moist woodland one mile west of Gillett Grove (9,695), Clay Co.

*Drepanocladus aduncus* (Hedw.) Warnst. var. *kneiffii* (Bry. Eur.) Warnst.

Kneif's D. or Sickiebranch Moss

Frequent in 2-4 feet of water in Dan Green Slough (9,731), Clay Co. Growing in 2-4 feet of water in Virgin Lake and Mud Lake (9,732), Palo Alto Co. Abundant locally.

*Drepanocladus aduncus* (Hedw.) Warnst. var. *polycarpus* (Bland.) Warnst.

f. *graciliens* Br. and Sch.

Many-fruited D. or Sickiebranch Moss

In a hanging bog one and one-half miles west of Osgood on the west side of the Des Moines River, Palo Alto Co.

*Entodon compressus* (Hedw.) G. Muell.

Slender Entodon

Two miles east of Spencer, H. S. Conard, Clay Co.

*Entodon seductrix* (Hedw.) C. Muell.

Round-stemmed Entodon

Two miles southeast of Spencer, H. S. Conard, Clay Co.

*Eurynchium hians* (Hedw.) J. & S.

Light-beaked Moss

Two miles southeast of Spencer, H. S. Conard, Clay Co.

*Eurynchium serrulatum* (Hedw.) Lindb.

Dark-beaked Moss

Wet soil along a stream in Wanata State Park at Peterson. Associated with *Mnium cuspidatum* and *Campylium hispidulum* (9,698), Clay Co.

*Hygroamblystegium irriguum* (Wils.) Loeske

Rigid Feather Moss

Moss Flora of N.A. 3:72. 1931.

*Amblystegium irriguum* Wils.

On the trunk of a willow, in springy ground at the entrance to Dickens along Highway 18 on Pickerel Run (9,705 and 9,709); on moist slopes, along the Little Sioux River, in Wanata State Park at Peterson, (9,701); Gillett Grove (9,715), Clay Co. Wet soil around a hanging bog in woods along the Des Moines River one and one-half miles west of Osgood (9,727 and 9,728), Palo Alto Co. Frequent.

*Hypnum patientiae* Lindb.

See Bryologist 43:128. 1941.

*H. arcuatum* Lind.

In a hanging bog one and one-half miles west of Osgood along the west side of the Des Moines River (9,970 and 9,971), Palo Alto Co.

*Leptodictyum riparium* (Hedw.) Warnst.

Waterside Feather Moss

See Moss Flora of N.A. 1:64. 1925.

*Amblystegium riparium* Br. and Sch.

Springy ground on the trunk of a willow at the entrance to Dickens along the Little Sioux River in Wanata State Park at Peterson (9,720); wet woods one mile west of Gillett Grove (9,714), Clay Co.

*Leptodictyum brevipes* (Card. and Thir.) Broth.

Short-leaved A. or Feather Moss

See Moss Flora of N.A. 1:66. 1928.

*Amblystegium brevipes* Card. and Thir.

On well curb at farm west of Spencer, H. S. Conard, Clay Co.

*Platygyrium repens* (Brid.) Bry. Eur.

Creeping platygyrium

Two miles southeast of Spencer, H. S. Conard, Clay Co.

#### LESKEACEAE (Leskea Family)

*Anomodon attenuatus* (Hedw.) Hüben.

Slender Anomodon

Wet woods, along the Little Sioux River, Wanata State Park, Peterson (9,719; two miles southeast of Spencer, H. S. Conard, Clay Co.

*Anomodon minor* (Beauv.) Lindb.

Blunt-leaved Anomodon

Slopes of hills along the Little Sioux River, Wanata State Park, Peterson (1,059); one mile west of Gillett Grove (9,718), Clay Co. Three miles southwest of Emmetsburg, H. S. Conard, Palo Alto Co.

*Anomodon rostratus* (Hedw.) Schimp.

Beaked Anomodon

Moist slope, along the Little Sioux River, Wanata State Park, (9,703), Clay Co.

*Leskea graciliens* Hedw.

Slender *Leskea*

Woodland or semi-open, on the bark of trees, the most common moss of the region.

*Leskea obscura* Hedw.

Border of a spring along the margin of Pickerel Run at the entrance to Dickens (9,707), Clay Co.

*Lindbergia brachyptera* (Mitt.) Kind. var. *Austinii* (Sull.) Grout

*Leskea austinii* Sull.

Austin's *Lindbergia*

*Fabroleskea austinii* Best.

*Lindbergia austinii* Benth.

Three miles southwest of Emmetsburg, H. S. Conard, Palo Alto Co.

Div. PTERIDOPHYTA  
(Fern Plants)

OPHIOGLOSSACEAE (Adder's Tongue Family)

*Botrychium virginianum* (L.) Sw.

Rattlesnake Fern

In a moist, shady ravine above the Little Sioux River in Wanata State Park (5,065), Clay Co. Rare.

POLYPODIACEAE (Fern Family)

*Adiantum pedatum* L.

Maidenhair Fern

Wooded slopes along the Little Sioux River, one mile west of Gillett Grove (936), Clay Co. Infrequent.

*Athyrium angustum* (Willd.) Presl.

Lady Fern

See *Rhodora* 19:190. 1917

*Asplenium filix-foemina* Bernh.

Once abundant along the slopes of wooded hills along the Little Sioux River, now nearly extinct (1,003), Clay Co.

*Cystopteris fragilis* (L.) Bernh.

Fragile Fern

Wooded hillsides along the Little Sioux River east of and in Wanata State Park, south of Peterson (897), Clay Co.

*Pteretis nodulosa* (Michx.) Nieuwl.

Ostrich Fern

See *Rhodora* 21:178. 1919.

*Onoclea struthiopteris* (L.) Hoffm.

Once abundant along the slopes of hills along the Little Sioux River at Peterson (1,003), Clay Co., now nearly extinct.

EQUISETACEAE (Horsetail Family)

*Equisetum arvense* L.

Common Horsetail

Common along streams and railroad embankments.

*Equisetum fluviatile* L.

Swamp Horsetail

Growing in one to two feet of water in Johnson's Slough, one-fourth mile east of Lost Island Lake (9,312 and 9,192), Palo Alto Co.

*Equisetum laevigatum* A. Br.

Smooth Horsetail or Scouring Rush

Three miles east of Spencer along the Little Sioux River (962), Clay Co. Frequent.

*Equisetum palustre* L.

Marsh Horsetail

In a bog along the West Fork of the Des Moines River, one and one-half miles west of Osgood (5,063), Palo Alto Co.

*Equisetum pratense* Ehrh.

Meadow Horsetail

Alluvial ground along the Little Sioux River one mile west of Gillett Grove (937); in Wanata State Park at Peterson (10,032); along Pickerel Run near Dickens, Clay Co.

Div. SPERMATOPHYTA  
Subdiv. GYMNOSPERMAE

PINACEAE (Pine Family)

*Juniperus virginiana* L.

Red Cedar

Hilltops along the West Fork of the Des Moines River (840), Palo Alto Co. Woodland at Gillett Grove and Wanata State Park at Peterson, along the Little Sioux River, Clay Co.

*Juniperus virginiana* L. var. *scopulorum* (Sarg.)

Lemmon Western Red Cedar

See Rhodora 43:349. 1941.

*Juniperus scopulorum* Sarg.

Gravelly prairie hills on the west border of Clay Co., in Peterson Twp., Sec. 30. Infrequent.

Subdiv. ANGIOSPERMAE

Class MONOCOTYLEDONEAE  
TYPHACEAE (Cat-tail Family)

*Typha angustifolia* L.

Narrow-leaved Cat-tail

Frequent in large stands in shallow alkaline lakes. Barringer's Slough, southwest border of Lost Island Lake, Round Lake, Mud Lake, Dewey's Pasture, and Elk Lake, Clay Co. Lost Island Lake, Mud Lake, Virgin Lake, and Johnson's Slough, Palo Alto Co.

*Typha angustifolia* L. var. *longespicata* Peck, Rept. N.Y. State Bot. in 47th Ann. Rep't of New York State Museum. 162, 1894.

Long-spiked Narrow-leaved Cat-tail

*T. angustifolia* var. *virginica* Tidestrom. Rhodora 13: 242. 1911.

See Trans. Wis. Acad. Sci. Arts and Let. 25:183-184. 1930.

Common in Round Lake and Mud Lake, probably more abundant than the typical variety. Pollen in tetrads, rachilla hard. Other hybrid forms with the general aspect of *T. angustifolia* or of its long-spiked variety are found.

*Typha latifolia* L.

Broad-leaved Cat-tail

Margins of shallow lakes, ponds, wet roadsides and marshes. Mud Lake, Dewey's Pasture, Barringer's Slough, Clay Co. Mud Lake (9,321), Lost Island Lake, Johnson's Slough, Palo Alto Co. *Typha latifolia* is less common than its long-spiked variety or *T. angustifolia* and its long-spiked variety.

*Typha latifolia* L. var. *elongata* (Dudley) Wiegand Bull. Cornell Univ. 2:102. 1886.

Long-spiked Broad-leaved Cat-tail

Abundant in shallow alkaline lakes. Most common in Mud and Round Lakes in both Clay and Palo Alto Counties. Pollen in tetrads, rachilla soft.

SPARGANIACEAE (Bur-reed Family)

*Sparganium americanum* Nutt.

American Bur-reed

Occurring in small patches toward the north side of Johnson's Slough (11,231), Lost Island Twp., Sec. 29., Palo Alto Co.

*Sparganium eurycarpum* Engelm.

Large Bur-reed

Abundant and widely distributed in the marginal zone of lakes, entirely filling ponds and occupying large areas in swamps and marshes, as a phase of emergent succession.

NAJADACEAE (Pondweed Family)

*Najas flexilis* (Willd.) Rostk. and Schmidt

Slender Naiad

Common in shallow water one-fourth feet in depth, in lakes and sloughs of Clay and Palo Alto Counties.

*Najas guadalupensis* (Spreng.) Morong

Guadalupe Naiad

In shallow water on the south side of Mud Lake (825); Round Lake (827); the bay on the west side of Trumbull Lake (101,133), Clay Co.

- Potamogeton americanus* Cham. and Schlecht. Long-leaved Pondweed  
*P. fluitans* Roth.  
*P. longites* Tuckerm.  
 Abundant in open water at Round Lake on the borders and west bay of Trumbull Lake, in spots on Virgin and Elk Lakes. Fruits heavily.
- Potamogeton amplifolius* Tuckerm. Large-leaved Pondweed  
 Located only in the east side of Round Lake.
- Potamogeton foliosus* Raf. var. *macellus* Fernald Leafy Pondweed  
 Mem. Gray Herb. 3:43. 1932.  
 In clear water in a shallow bay on the west side of Trumbull Lake (10,119 and 10,124); north end of Dan Green Slough in dark brown water (820); Round Lake, Clay Co. In the south bay of Virgin Lake (10,125), Palo Alto Co. Infrequent in Mud Lake. Widespread. Fruits regularly.
- Potamogeton gramineus* L. var. *graminifolius* Fries Grass-leaved Pondweed  
 See Rhodora 23:189. 1921.  
*P. graminifolius* (Fries) Freyer  
*P. heterophyllus* var. *graminifolius* (Fries) Wats. and Coulter  
 In clear water of a grassy marsh, outlet of Lost Island Lake (821 and 864), Clay Co. The dominant pondweed in Johnson's Slough (11,066), where it fruits abundantly, Palo Alto Co.
- Potamogeton natans* L. Common Floating Pondweed  
 Occasional, shallow water, east margin of Round Lake (823); West bay of Trumbull Lake (11,008 and 11,009); in shallow bay at south end of Virgin Lake, Clay Co. Some seasons more abundant than others.
- Potamogeton panormitanus* Biv. var. *minor* Biv. The Panormitanic Pondweed  
 See Mem. Gray Herb. 3:64. 1932.  
*P. gracilis* Fries  
*P. pusillus* var. *vulgaris* subvar. *interruptus* Robbins  
 Frequent in 2-3 feet of water in Round Lake (10,120); south bay of Virgin Lake, Palo Alto Co. Most of Iowa material has been called *P. pusillus*.
- Potamogeton pectinatus* L. Sago Pondweed  
 Widely distributed in practically all lakes and swamps. The chief pondweed in Dan Green Slough, Elk, Mud and Virgin Lakes. Common in Round Lake. Fruits heavily.
- Potamogeton richardsonii* (A. Benn.) Rydb. Clasping-leaved Pondweed  
*P. perfoliatus richardsonii* A. Benn.  
*P. perfoliatus lanceolatus* Robbins  
 Widely distributed and regularly recurrent, but not abundant except in Round Lake in large isolated colonies. Fruits sparingly.
- Potamogeton zosteriformis* Fernald Eel-grass Pondweed  
 See Mem. Gray Herb. 3: 36. 1932.  
*P. compressus* of auths. not L.  
*P. zosterifolius* of Am. auth. not Schumacher  
 Frequent in Round Lake and in the South Bay of Virgin Lake. Occasional in other lakes of the Ruthven area. Fruits sparsely.
- Zannichellia palustris* L. Horned Pondweed  
 Occurring in sandy areas in Round, Lost Island, Virgin, Mud Lakes, and Dan Green Slough, generally in clear shallow water. Very abundant in Mud Lake around the margins when the water is low.

## JUNCAGINACEAE (Arrow Grass Family)

- Triglochin maritima* L. Seaside Arrow-grass  
 Same habitat and location as *T. palustris* (722 and 747), Palo Alto Co. and more common. Six miles south of Dickens in a hanging bog (8,033), Clay Co.

*Triglochin palustris* L.

Marsh Arrow-grass

Marshy zone around springs outcropping from knolls five miles east of Ruthven (743 and 745), Palo Alto Co. Rare, but recurrent in hanging bogs.

## ALISMACEAE (Water-plantain Family)

*Alisma subcordatum* Raf.

Water Plantain

See Arkiv f. Bot. 24A<sup>1</sup>:19. 1932.

*Alisma Plantago-aquatica* of Am. auth. in part, not L.

Widespread around borders of lakes, ponds and sloughs constituting an early phase of the emergent flora. Abundant. Young leaves float on water.

*Lophotocarpus calycinus* (Engelm.) J. G. Smith

Large Lophotocarpus

Abundant locally on the northeast shore of Round Lake and along the outlet of Trumbull Lake (721 and 733), Clay Co. Medium Lake, Palo Alto Co.

*Sagittaria cuneata* Sheldon

Arum-leaved Arrowhead

*S. arifolia* Nutt.

Widely distributed in the Ruthven area around the edges of lakes, ponds and marshes. Produces lance-linear phyllodia and elongated petioles on the blade bearing leaves, which float when young.

*Sagittaria latifolia* Willd.

Broad-leaved Arrowhead

Widely distributed in the Ruthven Area, but less common than *S. cuneata*. Has variable leaves.

*Sagittaria graminea* Michx.

Grass-leaved Arrowhead

Upland shallow pond, along roadside one mile west of Round Lake (738), Clay Co. Margin of small pond in pasture, five miles east of Ruthven and one-fourth mile south of the viaduct in Highway 18 (731), Palo Alto Co.

## HYDROCHARITACEAE (Frog-bit Family)

*Anacharis canadensis* (Michx.) Planchon

Waterweed

See Contr. Lab. Bot. Univ. Montreal, No. 18, 40, 1931.

See also Rhodora 34: 114-116, 1932.

*Elodea canadensis* Michx. in part.

*Philotria canadensis* (Michx.) Britton in part.

*Elodea iowensis* Wylie

Clear, quiet water of Pickerel Run at the entrance to Dickens (735), Trumbull, Mud, Lost Island, Virgin, and Round Lakes.

*Vallisneria spiralis* L.

Freshwater Eel Grass

More than 50 colonies have been located on the northernmost bay of Trumbull Lake growing in silt in water 2-6 feet deep. The first collection was made by Jessup Low. Hayden (9,677 and 9,678), Clay Co. This plant was reported by J. L. Seal from Silver Lake, Palo Alto Co. in the Iowa Lake Bed Survey Report, 1917.

## GRAMINEAE (Grass Family)

*Agropyron pauciflorum* (Schwein.) Hitchc.

Slender Wheat Grass

*A. tenerum* Vasey

West of Mud Lake by the bridge (52) east of Spencer along the roadside (191). Moist meadow, four and one-half miles east of Ruthven. Frequent along lake banks.

*Agropyron repens* (L.) Beauv.

Quack Grass

Common throughout the region. Along railroads, roadsides, cultivated fields and pastures. Introduced from Europe.

*Agropyron subsecundum* (Link.) Hitchc.

Bearded Wheat Grass

*A. richardsonii* Schrad.

Five miles east of Ruthven in moist open prairie south of the viaduct over Highway 18, (7,089); one-half mile west of Ruthven, Jess Fufts (2,895), Palo Alto Co. Infrequent mostly in native prairie throughout the region.



*Agropyron Smithii* Rydb.

Western Wheat Grass

Common in Dewey's Pasture (114), Clay Co. Along railway four and one-half miles east of Ruthven (51), Palo Alto Co. Common along railroads and roadsides, also in cultivated fields and pastures.

*Agrostis alba* L.

Red Top

Widespread in low prairie, pastures, around ponds and in marshes.

*Agrostis hiemalis* (Walt.) B.S.P.

Hair Grass

Opposite Hughes prairie, dry gravelly soil roadside bank, Lost Island Twp., Sec. 20. 70'; five miles east of Ruthven, low meadow (512), Palo Alto Co.

*Alopecurus aequalis* Sobol

Short-awned Foxtail

See Rhodora 27:195. 1925.

*A. aristulatus* Michx.

*A. geniculatus* var. *aristulatus* (Michx.) Torr.

Not infrequent around the edges of shallow ponds.

*Alopecurus carolinianus* Walt.

Carolina Foxtail

Moist open ground, old fields and wet places.

*Andropogon furcatus* Muhl.

Tall Beardgrass or Tall Bluestem

Common in low prairie, occurring along roadsides.

*Andropogon scoparius* Michx.

Prairie Beardgrass or Short Bluestem

Common on upland prairie, also along roadsides.

*Aristida intermedia* Scribn. and Ball

Plains Aristida

Eight miles east of Ruthven along the C.M. and St.P. R.R. track at the edge of a swale (73), Clay Co.

*Aristida longiseta* Steud. var. *robusta* Merrill.

Three-awn Grass

Steep slopes of prairie hillsides, about one mile east of Peterson along Highway 10, (608), Clay Co.

*Aristida oligantha* Michx.

Prairie Three-awn

Five miles west of Emmetsburg, on a dry sandy bank along the roadside (39), Palo Alto Co.

*Avena fatua* L.

Wild Oats

Emmetsburg, L. H. Pammel (I.S.C. 98,450), Palo Alto Co.

*Beckmannia syzigachne* (Steud.) Fernald

American Slough Grass

*B. erucaeformis* of Am. auth. in part, not Host.

Growing sparsely about five miles east of Ruthven in a small pond south of the viaduct, over Highway 18. Sec. 25 of Highland Twp. (7,060 and 9,247); Sec. 30 of Lost Island Twp., Frances and Frederick Hamerstrom (I.S.C. 142,097), Palo Alto Co. Recurrent throughout the region.

*Bouteloua curtipendula* (Michx.) Torr.

Side-Oats Grama

Common on upland prairie slopes.

*Bouteloua gracilis* H.B.K.

Slender Grama Grass

*B. oligostachya* Torr.

Frequent on upland prairie knolls.

*Bouteloua hirsuta* Lag.

Hairy Grama Grass

Occurring on gravelly hilltops in prairie and persisting in blue grass pasture hilltops.

*Brachyelytrum erectum* (Schreb.) Beauv.

Rocky woodland slope along the Little Sioux River of Peterson (8,109), Clay Co.

- Bromus inermis* Leyss. Smooth Brome Grass  
One mile north of Ruthven, dry roadside (106), Palo Alto Co. railroad right-of-way, Freeman Twp., Sec. 14, Frances and Frederick Hamerstrom, (I.S.C. 142,110), Clay Co., Common.
- Bromus japonicus* Thunb. Japanese Brome Grass  
South shore of Lost Island Lake, Electric Park (103), Palo Alto Co.
- Bromus latiglumis* (Shear) Hitchc. Broad-glumed Brome Grass  
North wooded shore of Elk Lake (106), Clay Co.
- Bromus purgans* L. Canada Brome  
Occurring in rocky woods.
- Bromus tectorum* L. Downy Chess  
Common along roadsides and railroads, also in pastures. Introduced from Europe.
- Calamagrostis canadensis* (Michx.) Beauv. Reed-bent or Blue-joint Grass  
Common in swamps, marshes, low land bordering ponds and lakes. Abundant in the Outlet of Lost Island Lake, the marsh of Johnson's Slough, and Mud Lake. Common.
- Calamagrostis inexpansa* Gray Northern Reed Grass  
On hummocks in swampy areas, forming colonies at the border of marshes. Frequent.
- Calamovilfa longifolia* (Hook.) Scribn. Long-leaved Reed Grass  
Two miles south of Ruthven on a hill in a pasture west of Virgin Lake (9,279), Palo Alto Co.
- Cenchrus pauciflorus* Benth. Few-flowered Sandbur  
Margin of cornfield along Virgin Lake (119), Palo Alto Co. Sandy shore of Trumbull Lake, Frances and Frederick Hamerstrom (I.S.C. 142,104), Clay Co. Common along roadsides and in cultivated fields.
- Cinna arundinacea* L. Stout Woodreed Grass  
Floodplain of the Little Sioux River in shade or openings of maple-basswood woodland. Moist alluvial soil (605), Clay Co. Moist soil under shade of willows by roadside running around the northeast side of Lost Island Lake (9,883), Palo Alto Co.
- Dactylis glomerata* L. Orchard Grass  
South shore of Lost Island Lake, Palo Alto Co. Roadside near Spencer, Clay Co.
- Digitaria ischaemum* (Schreb.) Muhl. Smooth Crabgrass  
*Syntherisma humifusum* Rydb.  
Sandy beach south shore of Lost Island Lake (49); four miles east of Ruthven in an oatfield (122), Palo Alto Co. Common throughout the region in cultivated fields. Introduced from Eurasia.
- Digitaria sanguinalis* (L.) Scop. Tall Crabgrass  
*Syntherisma sanguinalis* (L.) Du Lac  
Frequent in cultivated soil and along roadsides.
- Echinochloa crusgalli* (L.) Beauv. Barnyard Grass  
Common in muddy margins of ponds, slough, and ditches, sandy beaches, also in cultivated fields. Abundant on mud flats following receding waters.
- Echinochloa crusgalli* (L.) Beauv. var. *mitis* (Pursh) Peterm. Beardless Barnyard Grass  
Frequent in same locations as the typical variety.
- Eleusine indica* (L.) Gaertn. Goose Grass  
Sandy beach at Electric Park on the south side of Lost Island Lake (72), Palo Alto Co. Rare. Naturalized from tropics of the Old World.

- Elymus canadensis* L. Nodding or Canada Wild-rye  
 South shore of Lost Island Lake (269), Palo Alto Co. Occurring in prairie along roadsides and banks. Frequent.
- Elymus canadensis* L. var. *robustus* (Scribn. and Smith) Mack. and Bush  
 Large Wild-rye  
*E. robustus* Scribn. and Smith.  
 More common than the typical variety.
- Elymus canadensis* L. var. *brachystachys* (Scribn. and Ball.) Farw.  
 Short-spiked Canada Wild-rye  
 Near Emmetsburg, Palo Alto Co., L. H. Pammel (I.S.C. 94,322).
- Elymus macounii* Vasey Macoun's Wild-rye  
 Moist, rolling prairie, also open roadsides. Frequent.
- Elymus virginicus* L. Virginia Wild-rye  
 Common both in prairie and along roadsides.
- Elymus virginicus* L. var. *glabriflorus* (Vasey) Bush Smooth-glumed Virginia Wild-rye  
 Along slopes and base of a high hill bordering the Little Sioux River, (620), Clay Co.
- Eragrostis cilianensis* (All.) Link Strong-scented Love Grass  
*E. major* Host.  
*E. megastachya* Link  
 Common along roadsides and in fields. Naturalized. From Europe.
- Eragrostis frankii* C. A. Meyer Frank's Eragrostis  
 On sandy loam in an opening of the trees in Wanata State Park at Peterson (7,523), Clay Co.
- Eragrostis hypnoides* (Lam.) B.S.P. Smooth Creeping Love Grass  
 Recurrent in drying ponds, drainage ditches, and on the muddy border of streams.
- Eragrostis pectinacea* (Michx.) Nees Purple Love Grass  
*E. carolinana* (Spreng.) Scribn.  
*E. purshii* Schrad.  
 Fields, waste places, open ground.
- Festuca elatior* L. Meadow Fescue  
 South shore of Lost Island Lake. Escaped from cultivation.
- Festuca shortii* Kunth Short's Fescue  
 Moist prairie around the margin of a slough in Dewey's Pasture (645), Clay Co.  
 Infrequent.
- Festuca obtusa* Sprengel Nodding Fescue  
*F. nutans* Spreng.  
 Wooded cut-over slope west of Gillett's Grove (644), Clay Co.
- Fluminea festucacea* (Willd.) Hitchc. River Grass  
 Abundant locally in swamps and sloughs growing in 6 inches to 2 feet of water in swamps southeast of Mud Lake (7,082), Palo Alto Co.; a prominent constituent of the emergent flora in the flora in the Outlet of Lost Island Lake (9,878); Dan Green Slough, Clay Co.
- Glyceria borealis* (Nash.) Batchelder Northern Manna Grass  
*Panicularia borealis* Nash.  
 Five miles east of Ruthven in a shallow pond one mile south of the viaduct over Highway 18, opposite Hughes Prairie (9,276), and in Johnson's Slough (10,928), Palo Alto Co.
- Glyceria grandis* S. Wats. American Manna Grass  
*Panicularia americana* MacM.  
 Frequent in swamps, margins of ponds and in hanging bogs.

- Glyceria striata* (Lam.) Hitchc. Tall Manna Grass  
*Panicularia nervata* Kuntze  
 Common on hummocks in swamps at edge of sloughs and in wet meadow.
- Hierochloa odorata* (L.) Beauv. Sweet Grass  
*H. Nashii* Kaczmarek  
 Wet meadows and hanging bogs and sometimes in roadside depressions. Infrequent.
- Hordeum jubatum* L. Wild Barley  
 Common around ponds and sloughs along roadsides and in pastures.
- Hystrix patula* Moench. Bottlebrush Grass  
*H. hystrix* (L.) Millspaugh  
 Moist rocky woods and shaded lake banks. Infrequent.
- Koeleria cristata* (L.) Pers. June Grass  
 Gravelly prairie knolls. Becoming scarce.
- Leersia oryzoides* (L.) Schwartz Rice Cutgrass  
 Common in swamps and low marshy areas.
- Leersia virginica* Willd. White grass  
 Low woods and moist places on hillsides.
- Leptochloa fascicularis* (Lam.) Gray Sprangletop  
*Diplachne fascicularis* (Lam.) Beauv.  
 Along the west muddy shore of Mud Lake opposite a farmhouse (13); sandy shores of Trumbull Lake, Clay Co. Sandy south shore of Lost Island Lake at Electric Park (9,876), Palo Alto Co. Infrequent.
- Lolium multiflorum* Lam. Italian Rye Grass  
 South shore of Lost Island Lake at Electric Park. Escaped from cultivation.
- Muhlenbergia asperifolia* (Nees and Mey.) Parodi Scratchgrass  
*Sporobolus asperifolius* Nees and Mey.  
 Abundant locally in alkaline soil around the edges of ponds, marshes, or lakes. Prominent in Dewey's Pasture (62), Clay Co. In a field five miles east of Ruthven south of the viaduct over Highway 18 (9,884), Palo Alto Co.
- Muhlenbergia brachyphylla* Bush. Short-leaved Muhlenbergia  
 Floodplain of the Little Sioux River in Wanata State Park at Peterson (614), Clay Co. In shade or open spaces.
- Muhlenbergia cuspidata* (Torr.) Rydb. Plains Muhlenbergia  
 Recurrent on dry, gravelly hilltops, prairie south of Virgin Lake (34); Hughes prairie two miles north of Lost Island Lake (24), Palo Alto Co. Vicinity of Gillett Grove, L. H. Pammel, (I.S.C. 53,491), Clay Co.
- Muhlenbergia foliosa* (Roem. and Schult.) Trin. Leafy Muhlenbergia  
 On a shaded bank at margin of a small stream which flows into the south side of Lost Island Lake on the Babcock Farm (616), Palo Alto Co. East bank of Round Lake (37), Clay Co. Moist thickets and low woods.
- Muhlenbergia mexicana* (L.) Trin. Wire-stemmed Muhlenbergia  
 Thickets, low woods and waste places.
- Muhlenbergia racemosa* (Michx.) B.S.P. Marsh Muhlenbergia  
 Common in moist meadows and low ground.
- Oryzopsis racemosa* (J.E. Smith) Ricker Black-fruited Mountain Rice  
 Rocky woods, Wanata State Park, Peterson (618), Clay Co.
- Panicum capillare* L. Old Witch Grass  
 Open ground, fields, dry lake beds, waste places.

- Panicum dichotomiflorum* Michx. Spreading Witch Grass  
Common along roadsides, fields and stirred soil.
- Panicum flexile* (Gattinger) Scribner Wiry Witch Grass  
Along the low shore of Medium Lake (8,220), Freedom Twp., Sec. 8, Palo Alto Co.
- Panicum leibergii* (Vasey) Scribn. Leiberg's Panicum  
Dry hilltop east of Lost Island State Park (44); prairie knolls, five miles east of Ruthven south of Highway 18 (628), Palo Alto Co.
- Panicum perlongum* Nash Long-stalked Panic Grass  
Dry, gravelly prairie east of the Outlet of Lost Island Lake (132); prairie knolls five miles east of Ruthven (625), Palo Alto Co.
- Panicum praecocius* Hitchc. and Chase Early-branching Panic Grass  
Prairie knolls five miles east of Ruthven south of Highway 18 (628), Palo Alto Co.
- Panicum scribnerianum* Nash Scribner's Panic Grass  
Frequent on high prairie, particularly on gravelly knolls.
- Panicum virgatum* L. Switchgrass  
Low and sometimes upland prairies, usually moist ground. Common.
- Panicum wilcoxianum* Vasey Wilcox's Panicum  
Appearing in tufts on the open spaces in grassland as a pioneer. Conspicuous on dry knolls in Dewey's Pasture (8,203), Clay Co. Prairie near Osgood (8,202), Palo Alto Co.
- Phragmites communis* Trin. Reed Grass  
See Rhodora 43:286. 1941.  
*P. communis* Trin.  
Abundant in 2 to 4 feet of water in Mud Lake, Round Lake and the Outlet of Lost Island Lake. Common in sloughs and along wet roadsides.
- Phalaris arundinacea* L. Reed Canary Grass  
Roadside bank two miles north of Round Lake (65); north margin of Mud Lake and of a slough in Dewey's Pasture (9,256), Clay Co.
- Poa annua* L. Annual Blue Grass  
Occasional in open ground of lawns or pastures.
- Poa compressa* L. Canada Blue Grass  
Wet meadow zone around sloughs, swamps, and marshes.
- Poa palustris* L. Fowl Blue Grass  
*Poa triflora* Gilib.  
Frequent in wet meadow and margins of swamps.
- Poa pratensis* L. Kentucky Blue Grass  
Widespread in pastures, roadsides and lawns.
- Phleum pratense* L. Timothy  
Common along roadsides and in fields, escaped from cultivation.
- Setaria lutescens* (Weigel) F.T. Hubb. Yellow Foxtail  
*S. glauca* (L.) Beauv. of Gray's Manual.  
Common in cultivated fields and along roadsides.
- Setaria verticillata* (L.) Beauv. Bur Bristlegrass  
Common in gardens and in neglected soil.
- Setaria viridis* (L.) Beauv. Green Foxtail  
Common in cultivated fields and along roadsides.

- Sorghastrum nutans* (L.) Nash Indian Grass  
*Andropogon nutans* (L.)  
 Chiefly upland prairie, not abundant.
- Spartina pectinata* Link Prairie Cordgrass  
*S. michauxiana* Hitchc.  
 Common around the edge of ponds, lakes, sloughs and in marshes. Sometimes growing on relatively dry banks and roadsides.
- Spartina pectinata* Link var. *suttiei* (Farw.) Fernald, Rhodora 35: 260. 1933.  
 Slender-spiked Prairie Cordgrass  
*S. michauxiana* var. *suttiei* Farw.  
 Pond across the road and north of Elk Lake, wet black clay, (58), Clay Co. Five miles east of Ruthven around small pond south of the viaduct (9,879), Palo Alto Co.
- Sphenopholis intermedia* (Rydb.) Rydb. Slender Wedgegrass  
 On the west side of Lost Island Lake near the bridge among weeds, along the beach (75), Clay Co. Swampy ground around cold springs which emerge from the foot of hills along the West Fork of the Des Moines River in a hanging bog association (707), Palo Alto Co.
- Sphenopholis obtusata* (Michx.) Scribn. Prairie Wedgegrass  
 Margin of Barringer's Slough on well drained, moist, sandy bank, Freeman Twp., Sec. 7 (112), Clay Co. West Bend, R. I. Cratty (I.S.C. 906,077), Palo Alto Co. Infrequent.
- Sporobolus asper* (Michx.) Künth Long-leaved Dropseed Grass  
 Steep prairie hillside, one-half mile east of Peterson (607), Clay Co. Dry gravelly prairie four miles north of Lost Island Lake (9,881), Palo Alto Co. Infrequent, but recurrent on dry banks, knolls, or level prairie.
- Sporobolus cryptandrus* (Torr.) A. Gray Sand Dropseed Grass  
 The dominant plant on the dune-like sand bank shore on the northeast side of Lost Island Lake (4); sandy northeast shore of Silver Lake (704), Palo Alto Co.
- Sporobolus heterolepis* Gray Prairie Dropseed Grass  
 Two miles northeast of Lost Island Lake, gravelly knoll in Hughes Prairie (23), Palo Alto Co. Steep, gravelly prairie hillside one-half mile east of Peterson (9,880), Clay Co. Usually occurring on dry gravelly hilltops or slopes.
- Sporobolus neglectus* Nash Small Dropseed Grass  
 On dry hilltops along the Little Sioux River in an over-grazed pasture (8,002), Clay Co. Five miles east of Emmetsburg in a depression along the roadside (47), Palo Alto Co. Frequent on disturbed soil.
- Sporobolus vaginaeflorus* (Torr.) Wood Sheathed Dropseed Grass  
 On the bank of Pickerel Run stream one-eighth mile east of Dickens, Jess Fults (2,901), Clay Co. Fairly common on dry eroded soil.
- Stipa spartea* Trin. Porcupine Grass  
 Not abundant but present on roadside banks, also crests and slopes of upland prairie.
- Zizania aquatica* L. var. *interior* Fassett Rhodora 26: 153-160. 1924. Wild Rice  
 A large colony grows in the swamp at the east border of Mud Lake (12 and 96); in Johnson's Slough (10,919); in the Inlet of Lost Island Lake (9,885), Palo Alto Co.

## CYPERACEAE (Sedge Family)

- Carex albursina* Sheldon White Bear Sedge  
 Moist soil in rocky woods, Wanata State Park, Peterson (8,305), Clay Co.
- Carex alopecoidea* Tuckerm. Foxtail Sedge  
 Dry bayou in the floodplain of the Little Sioux River, one mile east of Cornell (669); swampy woods, along the Little Sioux River at Gillett's Grove (670), Clay Co. Meadow east of Mud Lake (8,084), Palo Alto Co.



*Carex amphibola* Steud. var. *turgida* Fernald, Rhodora 44:311, 1942.

*C. grisea* of authors not Wahlenberg.

Moist wooded slopes along the Little Sioux River at Peterson (676, 682, and 8,088); wooded slopes along the Little Sioux at Gillett Grove (674, and 8,080), Clay Co. Frequent in rich woods.

*Carex annectans* Bick. var. *xanthocarpa* Wieg.

Yellow-fruited Sedge

Margin of a pond about 3 miles west of Graettinger (8,273), Palo Alto Co.

*Carex aquatilis* Wahlenb. var. *altior* (Rydb.) Fernald, Rhodora 44:295. 1942.

Water Sedge

*C. variabilis* Bailey var. *altior* Rydb.

*C. aquatilis* var. *substricta* Kükenth.

*C. substricta* (Kükenth) Mack.

Abundant locally, occurring in shallow water in zones or colonies around the Outlet of Lost Island Lake (640, 655, 656, 9,229, and 10,111) ponds and sloughs, Dewey's Pasture (9,233), Clay Co. Wet prairie five miles east of Ruthven (642, 771 and 8,086), Palo Alto Co.

*Carex atherodes* Spreng.

Awned Sedge

*C. trichocarpa* var. *aristata* (R.Br.) Bailey

North side of Round Lake, in water 8 inches to 1 foot deep, gravelly soil (54). Outlet of Lost Island Lake, swamp in one foot of water (648), Clay Co. Widespread in swamps.

*Carex bebbii* Olney

Bebb's Sedge

*C. tribuloides* Wahl. var. *Bebbii* L. H. Bailey

Wet prairie. Infrequent.

*Carex bicknellii* Olney

Bicknell's Sedge

Open prairie.

*Carex blanda* Dewey

Wooded slopes along the Little Sioux (8,078), Clay Co. Border of Mud Lake (185), Palo Alto Co.

*Carex brachyglossa* Mack.

Yellow-fruited Sedge

On hummocks, in swampy area, on the southwest side of Mud Lake (169), Clay Co.

*Carex brevior* (Dewey) Mack.

Few-headed Straw Sedge

See Am. Midl. Nat. 4:235. 1915.

*C. festucacea* var. *brevior* (Dewey) Fernald

Open grassland, Dewey's Pasture (794), Clay Co. Five miles east of Ruthven on a prairie knoll opposite viaduct over Highway 18 (666), Palo Alto Co. Frequent.

*Carex comosa* Boott

Bristly Sedge

North sandy beach, Round Lake (57); east sandy margin Round Lake in shallow water (143), Clay Co.

*Carex convoluta* Mack. Bull. Torr. Bot. Club 43:428. 1916.

Twisted-beaked Sedge

*C. rosea* of auth., not Schkuhr.

Southwest wooded shore of Mud Lake (179), Palo Alto Co.

*Carex cristatella* Britton

Crested Sedge

*C. cristata* Schwein., not Clairay

Roadside swale in water over black clay, Sioux Twp., Sec. 11 (193); swampy woods one mile east of Cornell, bayou of the Little Sioux River northeast of the bridge (667); low open woods along the Little Sioux at Gillett Grove (668); the floodplain of the Little Sioux River (668), Clay Co.

*Carex eburnea* Boott

Bristle-leaved Sedge

Rocky woods along the Little Sioux River at Peterson (8,263) Clay Co.

*Carex eleocharis* Bailey

Involute-leaved Sedge

*C. stenophylla* Wahl.

Dry, gravelly hilltop in Dewey's Pasture 115 feet above Mud Lake (236), Clay Co.

Dry gravelly hilltop in a bluegrass pasture on the west side of a slough, on the Needham farm about one mile south of Lost Island State Park (10,899), Palo Alto Co. Recurrent on dry gravelly hills.

*Carex emoryi* Dewey

Emory's Sedge

Around the edge of ponds in Dewey's Pasture (8,087), Clay Co. Five miles east of Ruthven southeast of the viaduct over Highway 18, growing in wet springy soil between the railroad track and fence (8,089), Palo Alto Co.

*Carex gravida* Bailey

Heavy Sedge

Frequent, occurring in tufts, in prairie, open woodland, along roadsides or margin of woods.

*Carex hystericina* Muhl.

Porcupine Sedge

Generally distributed occurring in colonies in cold springs, hanging bogs, on hummocks, in swamps, and on banks of streams. Solitary in wet meadows.

*Carex hitchcockiana* Dewey

Hitchcock's Sedge

Moist slopes of wooded hills along the Little Sioux River, in Wanata State Park, Peterson (681), Clay Co.

*Carex inflata* Hudson var. *utriculata* (Boott) Druce

See Rhodora 44:329. 1942.

*C. utriculata* Boott

*C. rostrata* var. *utriculata* f. *minor* (Boott) Kükenth.

Occupying a zone around the north side of Mud Lake (600); (602, 603 and 8,068); common in Dewey's Pasture in ponds and sloughs (600 and 9,228), Clay Co. In large areas at the southeast wooded shore of Mud Lake (168), Palo Alto Co.

*Carex interior* Bailey

Inland Sedge

*C. scirpoides* Schkuhr.

Wet meadow in the vicinity of springs in poorly drained calcareous soil about five miles east of Ruthven (8,042); on hummocks in a hanging bog along the Des Moines River about one and one-half miles southwest of Osgood (790), Palo Alto Co.

*Carex lacustris* Willd.

Lake Sedge

*C. riparia* Curtis in part.

*C. riparia* var. *lacustris* (Willd.) Kükenth.

Outlet of Lost Island Lake, west side along drainage ditch in large colonies reaching 25 feet in diameter (769, 788), Clay Co. In 1935 and 1936 the plants fruited abundantly though they are frequently sterile. Hanging bog along the west bank of the Des Moines River one and one-half miles southwest of Osgood (702) and (8,067), Palo Alto Co. Prominent in the large swamps of the region.

*Carex laeviconica* Dewey

Smooth-sheathed Awned Sedge

*C. trichocarpa* Muhl. var. *deweyi* Bailey, in part.

*C. trichocarpa* Muhl. var. *imberbis* Gray, in part.

*C. trichocarpa* Muhl. in part.

Floodplain of Little Sioux River at Cornell (647); two miles east of Spencer along stream bank (9,231), Clay Co. Occurring in the swamps of the region, but most abundant along river floodplains.

*Carex languinosa* Michx.

Woolly Sedge

*C. filiformis* Good var. *latifolia* Boeckl.

Forming sods around ponds, swales and marshes, occasional in wet meadow. Common.

*Carex lasiocarpa* Ehrh. var. *americana* Fernald

Slender Sedge

Rhodora 44:304. 1942.

*C. filiformis* of authors not L.

Frequent, wet margin of ponds and slough in Dewey's Pasture (828 and 9,214); Outlet of Lost Island Lake (663), Clay Co. On hummocks around the margin of Johnson's Slough (9,213); wet prairie five miles east of Ruthven (661), Palo Alto Co.

*Carex meadii* Dewey

Mead's Sedge

On prairie hillsides in the vicinity of Gillett Grove (8,073), Clay Co. About ten miles northeast of Lost Island Lake on rocky upland prairie (8,059), Palo Alto Co.

- Carex pennsylvanica* Lam. Pennsylvania Sedge  
Gravelly prairie ridges, river terraces and open woods. Common.
- Carex pennsylvanica* (Lam.) var. *digyna* Boeckl. Prairie Pennsylvania Sedge  
*C. pennsylvanica* of auth. in part.  
*C. heliophila* Mack. Torrey 13:15. 1913.  
Less frequent than the typical variety. Occurs on gravelly ridges.
- Carex praegracilis* Boott. Clustered Field Sedge  
*C. camporum* (Mack.) B. and B.  
Low terrace around Mud Lake, Dewey's Pasture, sandy to gravelly soil (199, 237 and 700), Clay Co. Frequent locally.
- Carex prairea* Dewey Prairie Sedge  
Around hilltop spring and wet prairie five miles east of Ruthven (245, 600 and 783), Palo Alto Co. Recurrent in typical locations.
- Carex retrorsa* Schw. Retrorse Sedge  
Dry bayou of the Little Sioux River (641), Clay Co. Abundant locally.
- Carex sartwellii* Dewey Sartwell's Sedge  
Shallow water, margin of Lost Island Lake (235); marsh southeast of Mud Lake in 6-18 inches of water (789); southwest margin of Mud Lake (180 and 182), Clay Co. Wet prairie five miles east of Ruthven south of the viaduct over Highway 18 (604, 786, and 8,063), Palo Alto Co.
- Carex scoparia* Schkuhr. Pointed Broom Sedge  
Low grassland southeast of Mud Lake (194), Palo Alto Co.
- Carex siccata* Dewey Dry Sedge  
Dry bank along the roadside from Wanata State Park to Peterson at the north side of the C. & N.W. RR crossing. The plant forms a tough sod (652), Clay Co.
- Carex sprengelii* Dewey Long-beaked Sedge  
*C. longirostris* Torr.  
Frequent along the slopes of the Little Sioux River at Peterson (780, 8,055 and 8,075), Clay Co.; northwest of Virgin Lake, shady bank (187), Palo Alto Co. Abundant locally.
- Carex stipata* Muhl. Awl-fruited Sedge  
Marshy zone of a hanging bog along the west side of the Des Moines River south of the bridge on the road to Osgood (671 and 8,064), Palo Alto Co. Abundant locally. Swampy area, floodplain of the Little Sioux River (673), Clay Co.
- Carex stricta* Lam. Tussock Sedge  
Margin of ponds and swamps, forming tussocks.
- Carex stricta* Lam. var. *strictior* (Dewey) Carey Diffuse Tussock Sedge  
Marsh, Dewey's Pasture (657), Clay Co. Wet prairie five miles east of Ruthven (658 and 659), Palo Alto Co. Forming beds, not in tussocks.
- Carex suberecta* (Olney) Britton Prairie Straw Sedge  
Hughes prairie, dry soil two miles northeast of Lost Island Lake (8,046), Palo Alto Co.
- Carex syncocephala* Carey Dense Long-beaked Sedge  
Occasional, south side of Lost Island Lake, sandy beach (166); abundant in pond Sec. 7, Walnut Twp. (8,258); border of Rush Lake after draining (7,572), Palo Alto Co.
- Carex tetanica* Schkuhr. Wood's Sedge  
Wet meadow around ponds and sloughs, sparsely distributed, singly or in clusters (662 and 703), Clay Co. Wet prairie five miles east of Ruthven (664, 770 and 785), Palo Alto Co.
- Carex tribuloides* Wahl. Blunt Broom Sedge  
Low open woods along the Little Sioux River (667), Clay Co.

- Carex vesicaria* L. Inflated Sedge  
In shallow ponds of Dewey's Pasture (9,226), Clay Co.
- Carex vulpinoidea* Michx. Fox Sedge  
Common in wet prairie growing in tufts in open prairie and in zones around ponds, margin of Lost Island Lake (198); Hughes Prairie (244); pond south of Lost Island Lake (655), Palo Alto Co. Frequent throughout the region.
- Cyperus aristatus* Rottb. var. *inflexus* (Muhl.) Kükenth. Awned Cyperus  
See Rhodora 44:52. 1942.  
*C. aristatus* Rottb.  
Sandy west beach of Lost Island Lake (201); sandy beach southeast shore of Lost Island Lake (693), Clay Co. South beach of Lost Island Lake, Palo Alto Co. Frequent.
- Cyperus diandrus* Torr. Low Cyperus  
Infrequent in wet soil around lake borders and sloughs.
- Cyperus engelmanni* Steud. Engelmann's Cyperus  
Dry bed of pond Outlet of Lost Island Lake (698), Clay Co.; sandy south shore of Lost Island Lake (697), Palo Alto Co.
- Cyperus erythrorhizos* Muhl. Red-rooted Cyperus  
South side of Lost Island Lake, sandy beach (225), Palo Alto Co. Dewey's Pasture, on sandy margin of Mud Lake (227), Clay Co.
- Cyperus esculentus* L. Yellow Nut-grass  
Along the floodplain of the Little Sioux River (639), Clay Co. Two miles south of Lost Island Lake around a small pond (206), Palo Alto Co.
- Cyperus ferruginescens* Boeckl. Coarse Cyperus  
See Rhodora 37:148-150. 1935.  
*C. spicius* Vahl. in part. of most recent authors.  
Sandy margin of Mud Lake (226); southeast shore of Round Lake on a sandy beach (694), Clay Co. Sandy south shore of Lost Island Lake (697), Palo Alto Co. Common.
- Cyperus rivularis* Kunth. Shining Cyperus  
Abundant in a zone with *Agrostis alba* along the northeast margin of Johnson's Slough (10,915); sandy beaches of Lost Island Lake (203 and 696), Palo Alto Co.
- Cyperus schweinitzii* Torr. Schweinitz's Cyperus  
North side of Virgin Lake, edge of sandy cornfield at margin of Virgin Lake (219); the dominant plant on the northeast dune-like sandy bank of Lost Island Lake (55), Palo Alto Co.
- Cyperus strigosus* L. Straw-colored Cyperus  
Common on sandy beaches, mud flats and ditches in late summer.
- Eleocharis acicularis* (L.) R. & S. var. *typica* Svenson Rh. 31:185-191. 1929. Needle Spike-rush  
Common in the beds of drying ponds, sloughs and around lake borders.
- Eleocharis calva* Torr. Creeping Spike-rush  
See Rhodora 31:68-70. 1929.  
*E. palustris* (L.) R. & S. var. *glaucescens* of many Am. auth.  
Sandy shores of lakes, margins of ponds, ditches, sloughs and hanging bogs. The commonest species in the Ruthven area.
- Eleocharis compressa* Sulliv. Flat-stemmed Spike-rush  
See Rhodora 34:215. 1932.  
*E. acuminata* (Muhl.) Nees  
Wet prairie and marshy area around hillside springs five miles east of Ruthven 758, 759, and 689), Palo Alto Co.

*Eleocharis englemanni* Steud.

## Englemann's Spike-rush

Growing in wet muddy soil around the margin of a shallow pond at the cross-roads north of Lost Island Lake six miles north of Ruthven, (9,197) and (9,198), Clay Co.

*Eleocharis macrostachya* Britton

## Pale Spike-rush

See Rhodora 41:56. 1939.

Five miles east of Ruthven in a shallow pond just southeast of the viaduct over Highway 18 (8,092), Palo Alto Co. Around ponds in Dewey's Pasture (9,236 and 7,009); sandy southwest shore of Round Lake (9,204); outlet of Lost Island Lake (7,010), Clay Co.

*Eleocharis obtusa* (Willd.) Schultes

## Blunt Spike-rush

Around the wet margin of a drying slough at the intersection of the roads to Mud Lake and to Round Lake, and north of the bridge over Lost Island Lake (9,199, 9,200, and 10,882), Clay Co.

*Eleocharis parvula* (R. & S.) Link var. *anachaete* (Torr.) Svenson

## Small Spike-rush

See Rhodora 31:177. 1929; 36:388. 1934.

*E. leptos* (Steudel) Svenson

*Scirpus nanus* Spreng.

Sandy south beach of Round Lake which is usually covered with water (690), Clay Co.

*Eleocharis smallii* Britton

## Small Spikerush

See Rhodora 41:64. 1939.

Five miles east of Ruthven around a small pond south of the viaduct over Highway 18 (9,237); shallow water of the bay southeast of Virgin Lake two miles south of Ruthven (8,252), Palo Alto Co.

*Eriophorum angustifolium* Roth

## Tall Cotton-grass

Margin of Mud Lake in Dewey's Pasture. W. L. Weber (409), Clay Co. Marshy zone around springs outcropping from knolls in the prairie (787 and 9,227), Palo Alto Co.

*Rhynchospora capillacea* Torr.

## Capillary Beaked-rush

Dominant plant in the marshy rush zone of a hanging bog. About six miles south of Dickens, Logan Twp., Sec. (8,040), Clay Co. Marshy zone around springs five miles east of Ruthven (742), Palo Alto Co.

*Scirpus acutus* Muhl.

## Hard-stemmed Bulrush

See Rhodora 22:55-56. 1920.

*S. occidentalis* (Wats.) Chase

Occurring in the permanent waters of shallow lakes including Dan Greene's Slough, Lost Island, Mud, Round, Elk, Silver, and Virgin Lakes.

*Scirpus americanus* Pers.

## Three-square or Chairmaker's Rush

Gravelly margin of Mud Lake (148 and 767); north margin of swamp along the east side of Dewey's Pasture (632); west margin of Trumbull Lake, Clay Co. Marshy zone around cold springs, five miles east of Ruthven (784), Palo Alto Co.

*Scirpus atrovirens* Muhl.

## Dark-green Bulrush

Marshy edge of Pickerel Run at Dickens (158), Clay Co.

*Scirpus fluviatilis* (Torr.) Gray

## Gray River Bulrush

Generally distributed. Great beds occur in the Outlet of Lost Island Lake, lower Mud Lake, and marginal zones or colonies in Round and Lost Island Lake, the bays of Trumbull Lake, Elk and Virgin Lakes, also in Dan Green Slough.

*Scirpus heterochaetus* (Wats.) Chase

## Pale Great Bulrush

In shallow sloughs and swamps of Dewey's Pasture (155, 635 and 8,057); along the north shore of Round Lake (635); the west bay of Trumbull Lake, Clay Co. Common in Johnson's Slough southeast of Lost Island Lake (8,056, 9,193, and 10,012), Palo Alto Co.

*Scirpus pallidus* (Britton) Fern.

Pale Bulrush

Around a spring, Pickerel Run, at Dickens (160); wet soil west border of Mud Lake (161); Dan Green Slough (1,072); Barringer's Slough (164), Clay Co. Between hummocks, wet, black soil southeast of Mud Lake (102); wet meadow southeast of Lost Island Lake (163), Palo Alto Co.

*Scirpus paludosus* A. Nels.

Prairie Bulrush

On the moist, sandy bed of Rush Lake which was in the summer of 1942 partly drained. July 23, 1942, (7604).

*Scirpus validus* Vahl.

Soft-stemmed Bulrush

Generally distributed occurring in colonies chiefly in shallow water of sloughs, ponds and around springs.

#### ARACEAE (Arum Family)

*Acorus calamus* L.

Sweet Flag or Calamus

Margin of a pond near dam on west side of Dewey's Pasture (715), Clay Co. Common in the bays on the south side of Virgin Lake (9,886), Palo Alto Co. Abundant in sloughs and swamps such as Barringer's, Smith's and in lakes such as Round and Mud.

*Arisaema atrorubens* (Ait.) Blume

Indian Turnip or Jack-in-the-Pulpit

See Rhodora 42:252. 1940.

*A. triphyllum* (L.) Schott

Rich wooded ravines along the Little Sioux River, in Wanata State Park south of Peterson (846); and Secs. 27 and 33 (10,039), Clay Co. Woods along the Des Moines River one and one-half miles west of Osgood (7,152), Palo Alto Co.

#### LEMNACEAE (Duckweed Family)

*Lemna minor* L.

Lesser Duckweed

Abundant in ponds, swamps, and shallow lakes of the region.

*Lemna trisulca* L.

Ivy-leaved Duckweed

Abundant in the shade of *Scirpus* and *Polygonum* in ponds and shallow lakes.

*Spirodela polyrhiza* (L.) Schleid.

Greater Duckweed

*Lemna polyrhiza* L.

Abundant in swamps, sloughs and shallow lakes, floating on open water.

*Wolffia punctata* Griseb.

Dotted Wolfia

Common on the surface water of sloughs, in swamps and on shallow lakes.

#### COMMELINACEAE (Spiderwort Family)

*Tradescantia bracteata* Small

Long-bracted Spiderwort

See Contr. Arn. Arb. 9:87. 1935.

Frequent, prairies, roadsides, railroads and open woods.

*Tradescantia canaliculata* Raf.

Reflexed Spiderwort

See Contr. Arn. Arb. 9:74. 1935.

*T. reflexa* Raf.

Infrequent, prairies, moist banks, and thickets.

#### PONTEDERIACEAE (Pickerel Weed Family)

*Heteranthera dubia* (Jacq.) MacM.

Water Stargrass

Rooting on mud flats or submerged in 1 to 2 feet of water. Round Lake (260 and 716); Trumbull Lake (10,107), Clay Co.; south bays of Virgin Lake (9,887), Palo Alto Co.

#### JUNCACEAE (Rush Family)

*Juncus balticus* Willd. var. *littoralis* Engelm.

Baltic Rush

Along the margins of lakes and on old lake terraces.

*Juncus bufonius* L.

Toad Rush

Sandy terrace along the north side of Mud Lake (210), Clay Co. Muddy border



of a spring in a pasture five miles east of Ruthven, one-half mile south of the viaduct over Highway 18 (643), Palo Alto Co.

*Juncus dudleyi* Wiegand Dudley's Rush  
Common around lakes and sloughs and in moist upland prairie.

*Juncus macer* S. F. Gray Slender Rush  
See Jour. of Bot. 68:366. 1930.  
*J. tenuis* of auth., not Willd.  
*J. monostichus* Bartlett.

Margin of a pond on the west side of Dewey's pasture, also growing in a denuded area from which vegetation has been scraped (792 and 793), Clay Co. Vicinity of Virgin Lake, Palo Alto Co. Found in moist gravelly soil at the edge of swales and ponds, also on hard, dry paths.

*Juncus nodosus* L. Knotted Rush  
Common at border of sloughs and swamps, margins of sloughs, springs and roadsides in black clay or gravelly soil.

*Juncus torreyi* Coville Torrey's Rush  
Roadside in wet, black Clay along Highway 18 at Dickens (212); wet margin of a pond in Dewey's Pasture (211), Clay Co. Five miles east of Ruthven, in wet prairie south of the viaduct over Highway 18 (830), Palo Alto Co.

#### LILIACEAE (Lily Family)

*Asparagus officinalis* L. Asparagus  
Occasional in open woods or grassland.

*Allium canadense* L. Meadow Garlic  
Moist meadow, or gravelly prairie. Infrequent.

*Allium stellatum* Ker. Wild Prairie Onion  
Frequent on dry prairie knolls or moist prairie.

*Allium tricoccum* Ait. Wild Leek  
Infrequent in low woods.

*Erythronium albidum* Nutt. Lamb's Tongue or Dogtooth Violet  
Infrequent on wooded banks, slopes, or floodplain.

*Lilium michiganense* Farwell Wild Tiger Lily  
Wet virgin prairie around ponds and sloughs; also seen in low, reverting clover hayland. Abundant locally in wet years.

*Lilium philadelphicum* L. Orange Wild Lily  
High prairie. Very rare. Formerly common.

*Polygonatum canaliculatum* (Muhl.) Pursh Large Solomon's Seal  
*P. giganteum* Dietr.  
*P. commutatum* (R. & S.) Dietr., in part.

Shady slopes of linden-maple woods along the Little Sioux River at Peterson (900), Clay Co. Wooded east shore of Lost Island Lake (9,338 and 5,096), Palo Alto Co.

*Smilacina racemosa* (L.) Desf. Spikenard or False Solomon's Seal  
Gillett Grove, L. H. Pammel (I.S.C. 53,485), Clay Co.

*Smilacina stellata* (L.) Desf. False Solomon's Seal  
Wooded hills along the Little Sioux River at Peterson (919, 5,071 and 10,040), Clay Co. Wooded east bank of Lost Island State Park (797), Palo Alto Co.

*Smilax ecirrhata* (Engelm.) S. Wats. Upright Green Brier  
General but not common in upland or rocky woods.

*Smilax herbacea* L. Smooth Carrion Flower  
Open woods, hillside along the Little Sioux River, Peterson (899), Clay Co.

*Smilax herbacea* L. var. *lasioneuron* (Hook.) A.D.C. Hairy-nerved Carrion Flower  
Infrequent in woods.

*Smilax hispida* Muhl. Hispid Green Brier  
Low woods along the Little Sioux River at Peterson (724), Clay Co.

*Trillium gleasoni* Fernald Rhodora 34:21-22. 1932. Drooping Wake Robin  
*T. declinatum* (Gray) Gleason not Raf.  
Shaded hillside along the Little Sioux River, Wanata State Park, south of Peterson (881) and (10,030), Clay Co.

*Trillium nivale* Riddell. Snow Trillium  
Woodland hillsides along the Little Sioux River at Peterson, Clay Co. Along the course of the Des Moines River, Palo Alto Co. Very rare, formerly abundant.

*Uvularia grandiflora* Smith Large-flowered Bellwort  
Open woodland along slopes of the Little Sioux River one mile west of Gillett Grove (930); Oak-Linden-maple woods along the Little Sioux River and its tributaries at Peterson (5,067), Clay Co.

*Zigadenus elegans* Pursh White Camas  
See Rhodora 37:256-57. 1935.  
*Zygadenus glaucus* Nutt.  
*Z. chloranthus* Richards  
Frequent in moist prairie.

#### AMARYLLIDACEAE (Amaryllis Family)

*Hypoxis hirsuta* (L.) Coville Yellow Stargrass  
Widely distributed in low prairie, or in moist openings in woods.

#### IRIDACEAE (Iris Family)

*Iris virginica* L. Wild Blue Flag  
See Ann. Mo. Bot. Gard. 15:256. 1926.  
*I. versicolor* of auth. not L.  
Abundant in swamps.

*Sisyrinchium campestre* Bicknell Blue-eyed Grass  
Fairly common on low prairies.

#### ORCHIDACEAE (Orchid Family)

*Cypripedium candidum* Muhl. White Prairie Lady's Slipper  
Wet prairie near a spring about five miles east of Ruthven south of the viaduct over Highway 18 (717), Palo Alto Co. Rare. Formerly frequent throughout the region around the margin of ponds.

*Cypripedium parviflorum* Salisb. var. *pubescens*. (Willd.) Knight Small-flowered Yellow Lady's Slipper  
Formerly occurring in the woods along the Little Sioux River in the vicinity of Peterson, Iowa. Reported by John McKee of Spencer who has a few transplanted specimens growing on his lawn. Clay Co.

*Liparis loeselii* (L.) Richard Twayblade  
In rush plain of ten five miles east of Ruthven (845), Palo Alto Co.

*Spiranthes cernua* (L.) Richards Lady's Tresses  
Low prairie opposite viaduct over Highway 18 on south side of highway, five miles east of Ruthven (718 and 11,195), Palo Alto Co.

#### CLASS DICOTYLEDONEAE SALICACEAE (Willow Family)

*Populus alba* L. White Poplar  
Occasional, scattered, escaped from cultivation. European.

- Populus deltoides* Marsh. Cottonwood  
*P. balsamifera* of recent auth., and perhaps of L., in part.  
 Lost Island Lake, L. H. Pammel, (I.S.C. 97,798), Palo Alto Co. General but less frequent than *P. Sargentii* Dode.
- Populus grandidentata* Michx. Large-toothed Poplar  
 Wooded ridges one mile west of Gillett Grove along the Little Sioux River (40,029), Clay Co. Infrequent.
- Populus nigra* L. var. *italica* Dur. Black Poplar  
 Two miles south of Virgin Lake (988), Palo Alto Co. Escaped from cultivation.
- Populus sargentii* Dode Sargent's Cottonwood  
*P. deltoides occidentalis* Rydb.  
 General, more frequent than *P. deltoides* on lake shores. Round Lake, (10,987) and (1,009), Clay Co. Lost Island Lake (841 and 10,988), Des Moines River (1,010), Palo Alto Co.
- Populus tremuloides* Michx. American Aspen  
 Frequent on dry hilltops and ridges in woods.
- Salix amygdaloides* Andersson Peach-leaved Willow  
 Common along streams, around ponds and lakes.
- Salix bebbiana* Sargent Bebb's Willow  
 Occasional around borders of marsh or in "hanging bogs" of the region.
- Salix cordata* Muhl. Heart-leaved Willow  
 The most common willow of the region. Occurring around lakes, along streams. A vigorous round-topped form is prevalent in the open, which has puberulent to pubescent stems and hairy buds and is referable to *S. missouriensis* Bebb. It probably should have varietal rank.
- Salix discolor* Muhl. var. *latifolia* Anderss. Pussy Willow  
 See Jour. Arnold Arb. 2:50. 1920.  
*S. discolor* Muhl. var. *eriocephala* (Michx.) Anderss.  
 Recurrent in hanging bogs along the Des Moines River (918, 1,032 and 6,066).
- Salix fragilis* L. Crack Willow  
 Frequent, lake shores. Virgin Lake (1,044); Silver Lake (1,028), Palo Alto Co. Lost Island Lake (10,998); Little Meadow Creek (1,021), Clay Co.
- Salix interior* Rowlee Bull. Torr. Bot. Club 27:253, 1900. Sandbar Willow  
*S. longifolia* Muhl. 1803 not Lam. (1778).  
*S. fluviatilis* Sarg. in part not Nutt.  
 Along lake banks, streams and marshes.
- Salix interior* Rowlee var. *pedicellata* (Andersson) Ball Long-leaved Sandbar Willow  
 Canad. Field-Nat. 50:175, 1926.  
 Between Round and Trumbull Lakes on the south side of the outlet (6,081), Clay Co. Near the road along the wet, grassy margin of Johnson's Slough (10,992), Palo Alto Co.
- Salix nigra* Marshall Black Willow  
 Occurs on the tributaries of the Des Moines River and also on the Little Sioux. West Bend, L. H. Pammel, (I.S.C. 96,036), Palo Alto Co. Gillett Grove (7,529) and Peterson (9,973), Clay Co.
- Salix petiolaris* J. E. Smith Slender Willow  
 Northwest border of Elk Lake (1,041), Clay Co. Swale between knolls, Hughes prairie two miles northeast of Lost Island Lake (108), Palo Alto Co.
- Salix subsericea* (Anderss.) Schneider  
 Peat bog north of Rock Island gravel pit at Graettinger, B.O. Wolden, 1,440, Palo Alto Co.
- Salix humilis* Marsh. var. *rigidiuscula* (Anderss.) Fernald. Prairie Willow  
 Occasional along wooded ridges and in open prairie.

## JUGLANDACEAE (Walnut Family)

- Carya cordiformis* K. Koch Bitternut Hickory  
Common on slopes of wooded hills and ravines.
- Jugland nigra* L. Black Walnut  
Frequent on floodplains and slopes of hills.

## BETULACEAE (Birch Family)

- Betula pendula* Roth. Pendant White Birch  
Growing along the roadside two miles north of Ruthven near Electric Park.  
Introduced.
- Corylus americana* Marsh. American Hazel-Nut  
Common at the edge of woods.
- Ostrya virginiana* (Mill.) K. Koch Hop Hornbeam  
Common in upland woods in the secondary tree layer.

## FAGACEAE (Oak Family)

- Quercus borealis* Michx. Northern Red Oak  
Slopes of hills along the Little Sioux River at Gillett Grove and Peterson, Clay Co.  
Woods along the Des Moines River, Palo Alto Co.
- Quercus borealis* Michx. var. *maxima* Sarg. Large-fruited Northern Red Oak  
Upland woods, slopes of hills. Infrequent.
- Quercus ellipsoidal* E.J. Hill Hill's Oak  
Slope of hill along the Little Sioux River at Wanata State Park (957) Gillett  
Grove, L.H. Pammel, (I.S.C. 74,457), Clay Co.
- Quercus macrocarpa* Michx. Burr Oak  
The dominant oak of the region, growing in almost pure stands along rocky lake  
shores. Scattered in woodland.
- Quercus velutina* Lam. Black Oak  
Uncommon in upland slopes along the Little Sioux River in Wanata State Park  
at Peterson (956), Clay Co.; Lost Island Lake, L.H. Pammel, (I.S.C. 98,854).

## URTICACEAE (Nettle Family)

- Cannabis sativa* L. Hemp  
Common along alluvial soil along waterways, roadsides, dumpheaps and waste  
areas.
- Celtis occidentalis* L. Hackberry  
Frequent on floodplains in woodland.
- Celtis occidentalis* L. var. *crassifolia* (Lam.) Gray Rough-leaved Hackberry  
Lost Island Lake, L.H. Pammel (I.S.C. 98,808), Palo Alto Co.
- Humulus lupulus* L. Common Hop  
Hedge opposite Johnson's Slough, northeast of Lost Island Lake, Palo Alto Co.  
Infrequent.
- Laportea canadensis* (L.) Gaud. Wood Nettle  
Shady floodplain of the Little Sioux River in Wanata State Park (3,095), Clay  
Co. East shady shore of Lost Island Lake (3,096), Palo Alto Co.
- Morus alba* L. White Mulberry  
Roadside at entrance to Lost Island State Park (3,092), Palo Alto Co.
- Parietaria pennsylvanica* Muhl. Pellitory  
In a hanging bog along the Des Moines River one and one-half miles southwest  
of Osgood (5,061), Palo Alto Co.

- Pilea pumila* (L.) Gray Clear Weed  
 Low shady woods in rich alluvial soil, Wanata State Park, Peterson (3,097), Clay Co. Hilltop bog, five miles east of Ruthven south of viaduct over Highway 18 (3,098), Palo Alto Co.
- Ulmus americana* L. American or White Elm  
 Common around lake shores and in upland and lowland woods.
- Ulmus fulva* Michx. Slippery or Red Elm  
 Common around lake shores and in woods along streams.
- Urtica procera* Muhl. Slender Nettle  
 See Rhodora 28:192-95. 1926.  
*Urtica gracilis* of most Am. auth., not Ait.  
 Gillett Grove, L.H. Pammel (I.S.C. 74,439). Roadside four miles east of Ruthven, W. A. Weber (1,262), low wet roadside east of Lost Island Lake (3,099), Palo Alto Co. General, roadsides, open woodland and alluvial soil.

## SANTALACEAE (Sandalwood Family)

- Comandra umbellata* (L.) Nutt. Umbellate Bastard Toadflax  
 Common, upland prairie. General.
- Comandra richardsiana* Fern. Richards' Bastard Toadflax  
 Prairie one mile east of Peterson (903), Clay Co. Usually on woodland semi-open ridges. Infrequent, but regularly recurrent.

## ARISTOLOCHIACEAE (Birthwort Family)

- Asarum canadense* L. var. *acuminatum* Ashe Wild Ginger  
*A. acuminatum* (Ashe) Bicknell  
 Oak-maple woods along the Little Sioux, Gillett Grove (933), Clay Co.

## POLYGONACEAE (Buckwheat Family)

- Polygonum aviculare* L. Dooryard Knotweed  
 Five miles east of Ruthven along roadsides (6,093), Palo Alto Co. Common in hard, dry soil.
- Polygonum convolvulus* L. Black Bindweed  
 Common along roadsides and in cultivated fields.
- Polygonum coccineum* Muhl. Pointed Water Smartweed or Tanweed  
 See Rhodora 27:162. 1925.  
*P. muhlenbergii* (Meisn.) Wats.  
*Persicaria muhlenbergii* (Wats.) Small in part.  
 Marshy area around an oxbow cut-off of Meadow Creek two miles north and two miles east of Spencer (10,051), Clay Co. In two feet of water in Johnson's Slough, one mile southeast of Lost Island Lake (11,199), Palo Alto Co.
- Polygonum coccineum* Muhl. var. *pratincta* (Greene) Stanford Meadow Water Smartweed  
 See Rhodora 27:165. 1925.  
*Persicaria pratincta* Greene  
 Growing in 6 inches to 1 foot of water on the north side of Johnson's Slough, one mile east of Lost Island Lake (11,334), Palo Alto Co.
- Polygonum coccineum* Muhl. forma *terrestre* (Willd.) Stanford Terrestrial Water Smartweed  
 See Rhodora 27:162. 1925.  
*P. coccineum* Muhl. var. *terrestre* Willd.  
*Persicaria muhlenbergii* (Meisn.) Wats. in part.  
 Wet roadside along the south side of Highway 18. Plants five feet tall, fruiting abundantly (3,040); margin of a pond about one-half mile north of Elk Lake (3,038); margin of Dan Green Slough (6,017), Clay Co. In 1 foot of water in a ditch, Hughes prairie (3,039 and 3,041), Palo Alto Co.

*Polygonum coccineum* Muhl. var. *rigidulum* (Sheldon) Stanford  
Inflated Water Smartweed

See Rhodora 27: 165. 1925.

*P. rigidulum* Sheldon

*Persicaria rigidula* (Sheldon) Greene

Growing in 2 to 3 feet of water rooted in the silt of Round Lake (6,060), Clay Co.  
Occasional plants with submerged stems much inflated.

*Polygonum erectum* L. Upright Knotweed  
Roadside in Dewey's Pasture (6,092), two miles east of Spencer, roadside (9,395), Clay Co.

*Polygonum Hydropiper* L. var. *projectum* Stanford  
Common Smartweed or Water Pepper

See Rhodora 29:86. 1927.

*P. Hydropiper* (L.), in part

*Persicana Hydropiper* (L.) Opiz.

Shallow ponds along the south shore of Lost Island Lake (9,029), Palo Alto Co.  
Dewey's Pasture around ponds (6,063), wooded floodplain along the Little Sioux River, Wanata State Park (11,343), Clay Co.

*Polygonum lapathifolium* L. Dock-leaved or Pale Knotweed

See Rhodora 23: 258-59. 1921.

*P. lapathifolium* var. *nodosum* (Pers.) Weinmann

Sandy south shoreline of Lost Island Lake (11,339), Palo Alto Co.

*Polygonum natans* A. Eaton forma *genuinum* Stanford Blunt-leaved Water Smartweed  
See Rhodora 27:158. 1925.

*P. natans* A. Eaton

*P. fluitans* Eaton

Near the rocky shore of an island in Virgin Lake (6,016), abundant in a shallow marsh two miles north of Lost Island Lake (6,051), Palo Alto Co. In 2 feet of water toward the north side of Mud Lake (6,052), also abundant in the Outlet of Lost Island Lake, Clay Co.

*Polygonum natans* A. Eaton forma *hartwrightii* (Gray) Stanford, Rhodora 27:161. 1925.  
Hartwright's Water Smartweed

*P. hartwrightii* Gray

*P. amphibium* L. var. *hartwrightii* (Gray) Bissell

Frequent in late summer or in dry seasons.

*Polygonum pennsylvanicum* L. Pennsylvania Knotweed  
Common in cultivated fields and along roadsides.

*Polygonum pennsylvanicum* L. var. *laevigatum* Fernald, Rhodora 19:73. 1917.  
Smooth-leaved Pennsylvania Knotweed  
Roadside ditch 2 miles northeast of Spencer (3,079), Clay Co.

*Polygonum persicaria* L. Lady's Thumb  
Sandy south beach of Lost Island Lake (3,080), Palo Alto Co. Along the shore of Mud Lake (3,081); low marshy land along the rocky outlet of Lost Island Lake (11,338), Clay Co. Abundant in low cultivated fields.

*Polygonum punctatum* Ell. Dotted Smartweed

*P. acre* H.B.K., not Lam., in part.

*P. acre* var. *leptostachyum* Meisn., in part.

*Persicaria punctata* (Ell.) Small

Abundant in wet land along streams, around ponds and bordering marshes.

*Polygonum ramosissimum* Michx. Bushy Knotweed  
Frequent around lakes, ponds, and wet roadsides.

*Polygonum scandens* L. Climbing False Buckwheat  
South shore of Lost Island Lake in the shade of trees (6,053), Palo Alto Co. Shady pasture southwest of Gillett Grove (6,013), floodplain of the Little Sioux River at Wanata State Park (6,054), Clay Co.



*Polygonum virginianum* L. Virginia Knotweed

Shaded woods along the floodplain of the Little Sioux River at Wanata State Park one-half mile south of Peterson (895 and 6,055), Clay Co.

*Rumex acetosella* L. Sheep Sorrel

Common on roadside bank and in pastures.

*Rumex altissimus* Wood Tall Dock

About three miles east of Spencer. Roadside (9,391), Clay Co.

*Rumex britannica* L. Great Water Dock

Five miles east of Ruthven in the center of a hilltop bog (3,088), Palo Alto Co. Wet meadow in an oxbow of Little Meadow Creek (3,085), Clay Co. Generally distributed in sloughs and swamps. Not common.

*Rumex crispus* L. Curled or Narrow Dock

Roadsides, ponds, sloughs and pastures. Common.

*Rumex maritimus* L. var. *fueginus* (Philippi) Dusén. Golden Dock

See Rhodora 17:80. 1915.

*R. fueginus* Phil.

*R. persicarioides* Trelease

Frequent around the low shores of lakes, swamps, ditches and populating mud flats in late summer.

*Rumex mexicanus* Meisn. White, Pale or Willow-leaved Dock

West Bend, R.I. Cratty, (I.S.C. 96,075), Palo Alto Co.

*Rumex verticillatus* L. Swamp or Whorled Dock

Two miles east of Spencer, roadside (9,394), Clay Co.

#### CHENOPODIACEAE (Goosefoot Family)

*Atriplex patula* L. var. *hastata* (L.) Gray Halberd-leaved Orache or Spear Scale  
Emmetsburg, L.H. Pammel, (I.S.C. 94,314), Palo Alto Co.

*Chenopodium album* L. Lamb's Quarter or White Pigweed

Gillett Grove, L.H. Pammel (I.S.C. 74,441), Clay Co. Very common. Roadsides, barnyards, waste grounds.

*Chenopodium gigantospermum* Aellen Maple-leaved Goosefoot

See Fedde. Rep. Spec. Nov. 26:144. 1929.

*C. hybridum* of Am. auth., not L.

Low shady woodland west of Gillett Grove (4,011), Clay Co. Rich soil in shade (4,012), Palo Alto Co.

*Chenopodium glaucum* L. Oak-leaved Goosefoot

Sandy north beach of Lost Island Lake at edge of water (4,016), Palo Alto Co.

*Chenopodium leptophyllum* Nutt. Narrow-leaved Goosefoot

Roadside north of Mud Lake (4,018), Clay Co.

*Chenopodium rubrum* L. Red Goosefoot

Muddy shore of Mud Lake from which water had receded after a dry period (4,015); sandy southwest shore of Lost Island Lake south of the bridge during a dry season (4,013); frequent on the dry bed of Barringer's Slough, Clay Co. A plant of salt marshes.

*Kochia scoparia* (L.) Schrad. Kochia

North shore of Lost Island Lake (4,020); neglected ground and dooryards, Ruthven, W. A. Weber (1,220), Palo Alto Co. Frequent.

*Salsola kali* L. var. *tenuifolia* G. F. W. Mey. Russian Thistle

Sandy northeast shore of Lost Island Lake (4,019), Palo Alto Co. General along railroad embankments and waste areas.

## AMARANTHACEAE (Amaranth Family)

- Amaranthus blitoides* Wats. Prostrate Pigweed  
Infrequent in cultivated ground and roadsides. General.
- Amaranthus graecizans* L. Tumbleweed  
Occurring along railroad ways, roadsides, vacant lots and at the edge of cultivated fields.
- Amaranthus hybridus* L. Green Pigweed  
Infrequent. General.
- Amaranthus retroflexus* L. Upright Pigweed  
Sandy shore along the northeast side of Lost Island Lake (4,006), Palo Alto Co. Common along roadsides and in cultivated fields (4,004), Clay Co.
- Acnida tuberculata* Moq. Western Water-hemp  
Dry ditch along Highway 18, south of Dickens (4,008), Clay Co. Northeast sandy shore of Lost Island Lake (4,009), Palo Alto Co. Frequent in cultivated fields and along roadsides.

## NYCTAGINACEAE (Four-o'clock Family)

- Mirabilis hirsuta* (Pursh) MacM. Hairy Umbrellawort or Wild Four O'clock  
See Field Mus. Pub. Bot. 8:305. 1931.  
*Allonia hirsuta* (Pursh) Mac M.  
*Oxybaphus hirsutus* Sweet  
High southwest shore of Lost Island Lake in native grassland, also in an oatfield (4,021), Palo Alto Co. Along the shore of Round Lake, Clay Co. Frequent.
- Mirabilis nyctaginea* (Michx.) MacM. Smooth Wild Four O'clock  
See Field Mus. Pub. Bot. 8:305. 1931.  
*Allonia nyctaginea* Michx.  
*Oxybaphus nyctagineus* Sweet  
Along roadside between Round and Trumbull Lakes (4,021), Gillett Grove, L.H. Pammel, (I.S.C. 53, 482), Clay Co.; frequent around lake banks and along roadsides throughout the region.

## CARYOPHYLLACEAE (Pink Family)

- Cerastium vulgatum* L. var. *hirsutum* Fries Hairy Mouse-eared Chickweed  
See *Rhodora* 22:178. 1920.  
*C. vulgatum* of auth., not L.  
In the shade of willows at Electric Park, near the shore of Lost Island Lake, (10,166), Palo Alto Co.
- Lychnis alba* L. White Campion  
Common along roadsides. Sometimes growing in fields.
- Saponaria officinalis* L. Bouncing Bet, Soapwort  
Occasional, escaped from cultivation.
- Saponaria vaccaria* L. Cow-herb  
Along the right-of-way of the C.M. and St. P. R.R. at the station in Ruthven, (9,168), Palo Alto Co.
- Silene antirrhina* L. Sleepy Catchfly  
Roadside north of Webb (10,165). Sandy north shore of Lost Island Lake (10,164). Clay Co. Frequent along roadsides, edges of fields on wood, on bare soil, usually in the open.
- Silene dichotoma* L. Forked Catchfly  
Near Spencer, collected by the Farm Bureau Office (I.S.C. 114, 894), Clay Co.
- Silene stellata* (L.) Ait. Starry Campion  
Frequent on lake shores and borders of wood.

*Stellaria longifolia* Muhl. Long-leaved Stitchwort  
*Alsine graminea* (L.) Britton  
 Roadside vicinity of Ruthven (10,163), Palo Alto Co.

*Stellaria media* (L.) Cyrill Common Chickweed  
 Common on shaded lawns, around greenhouses and cultivated planting. Introduced.

#### PORTULACACEAE (Portulaca Family)

*Claytonia virginica* L. Spring Beauty  
 Oak-linden-maple woodland slopes one-half mile north of Peterson. Common locally (944), Clay Co. Common locally. Infrequent.

*Portulaca oleracea* L. Purslane  
 On steep slopes of pasture hillsides, forming a mat over the soil where blue grass had disappeared during the drought of 1936 (2,060), Clay Co. Occurring on denuded soil and in cultivated fields.

#### CERATOPHYLLACEAE (Hornwort Family)

*Ceratophyllum demersum* L. Hornwort or Coontail  
 Common in shallow lakes and swamps. Grows in water 2 to 3 feet in depth.

#### NYPHAEACEAE (Water Lily Family)

*Nelumbo pentapetala* (Walt.) Fernald, Rhodora 36:23-24. 1934  
 American Lotus or Chinquapin

*Nelumbo lutea* (Willd.) Pers.  
 West of the center of Round Lake Colony. The colony is about 50 feet in diameter, close to *Scirpus acutus* (9,646), Clay Co.

*Nuphar advena* Ait. Yellow Pond-lily or Spatterdock  
 See Field Mus. Pub. Bot. 8:310. 1931.  
*Nymphaezanthus advena* Ait.  
 Filling an oxbow cut-off in Little Meadow Creek, three miles north and two miles east of Spencer (3,000), Clay Co.

*Nymphaea tuberosa* Paine Tuberous-rooted White Water-lily  
 See Rhodora 18:120. 1916; 39:407. 1937.  
*Castalia tuberosa* (Paine) Greene.  
 Not collected in this survey. Reported for both counties in early years.

#### RANUNCULACEAE (Crow foot Family)

*Actaea rubra* (Ait.) Willd. Red Baneberry  
 Wooded slopes along the Little Sioux River one mile west of Gillett Grove (921 and 946), Clay Co.

*Anemone canadensis* L. Canada Anemone  
 Common along roadsides, along streams and in low prairie.

*Anemone caroliniana* Walt. Carolina anemone  
 Infrequent in openings of the grass pasture or in native grassland on gravelly soil. Associated with *Draba reptans*, *Cogswellia orientalis* in a Bouteloua sod (7,530), Sec. 19, Peterson Twp., Clay Co.

*Anemone cylindrica* A. Gray Long-fruited Anemone or Thimbleweed  
 Upland prairie, gravelly hilltops. Frequent.

*Anemone patens* L. var. *wolfgangiana* (Bess.) Koch. Pasque Flower  
 Formerly abundant on upland prairie on gravelly knolls. At present infrequent except on rocky prairie hills and pastures around Peterson where it is frequent. One-half mile east of Peterson on high rocky prairie hilltop (5,053), one mile east of Gillett Grove (2,064), gravelly prairie slope north of Dan Green Slough (2,074), Clay Co. Prairie hilltop northwest of Needham's Slough, south of Lost Island Lake, gravelly prairie hillside two miles northeast of Emmetsburg (9,204), Palo Alto Co.

- Anemone quinquefolia* L. Wood Anemone  
Wooded slopes along the Little Sioux River, Gillett Grove and Peterson (917, 5,054 and 10,033), Clay Co.
- Anemone virginiana* L. Virginia Anemone  
Infrequent in woods of the region.
- Aquilegia canadensis* L. Columbine  
Rocky woods, and lake shores. Frequent.
- Caltha palustris* L. Marsh Marigold  
Infrequent in marshy ground around ponds and in hanging bogs.
- Clematis virginiana* L. Virgin's Bower  
Common around wooded borders of Lakes.
- Delphinium virescens* Nutt. White Larkspur  
See Rhodora 39: 20. 1937.  
*D. albescens* Rydb.  
Infrequent on upland prairie.
- Hepatica acutiloba* DC. Hepatica or Liverwort  
Shaded slopes along the Little Sioux River at Peterson (892), Clay Co.
- Isopyrum biternatum* (Raf.) T. & G. False Anemone  
Slopes of wooded hills along the west fork of the Des Moines River (2,098), wooded slopes, Gillett Grove and Peterson, Clay Co.
- Ranunculus abortivus* L. Small-flowered Crowfoot  
Shaded or open floodplains of streams. Common.
- Ranunculus cymbalaria* Pursh Seaside Crowfoot  
Common around ponds in Dewey's Pasture and along the edge of Mud Lake (2,067), Clay Co. Swamp southeast of Mud Lake (2,081), Palo Alto Co. Frequent.
- Ranunculus flabellaris* Raf. Yellow Water Crowfoot  
See Rhodora 38:171. 1936.  
*R. delphinifolius* Torr.  
In water in a green ash grove west of Trumbull Lake (9,438); in ponds in Dewey's Pasture (2,077, Clay Co. Five miles east of Ruthven in a small pond south of the viaduct (9,433), Palo Alto Co.
- Ranunculus longirostris* Godron Stiff Water Crowfoot  
See Rhodora 38:42. 1936.  
*R. circinatus* of authors  
*Batrachium circinatum* of Manuals  
Rare in the region.
- Ranunculus trichophyllus* Chaix. var. *typicus* Drew White Water Crowfoot  
See Rhodora 38:18-29. 1936.  
*Ranunculus aquatilis* var. *capillaceus* DC.  
*Batrachium trichophyllum* (Chaix) F. Shultz  
In quiet water of Pickerel Run bayou, at the entrance to Dickens (2,066), Clay Co. Ponds in pasture north of Mud Lake near the bur oak woods (2,080), Palo Alto Co.
- Ranunculus pennsylvanicus* L. Bristly Crowfoot  
Marshy edge of Dan Green Slough (2,082); occasional around a pond at the crossroads north of Lost Island Lake (9,439), Clay Co. In a hanging bog along the Des Moines River one and one-half miles southwest of Osgood (7,036), Palo Alto Co.
- Ranunculus rhomboideus* Goldie Prairie Crowfoot  
See Rhodora 38:176. 1936.  
*R. ovalis* Raf.  
Open gravelly hill one mile east of Gillett Grove (2,065), Clay Co. Rocky prairie.

hillside six miles northeast of Lost Island Lake State Park (7,006); one mile northeast of Graettinger (2,084), Palo Alto Co.

*Ranunculus sceleratus* L.

Celery-leaved Crowfoot

Around the margin of Dan Green Slough (2,078), Clay Co. Hanging bog along the west side of the Des Moines River one and one-half miles west of Osgood (7,037); north and south shores of Virgin Lake (2,087), Palo Alto Co.

*Ranunculus septentrionalis* Poir.

Swamp Buttercup

Low moist woods and wet prairie. Common.

*Thalictrum dioicum* L.

Early Meadow Rue

Wooded slopes along the Little Sioux River at Peterson (5,051), Clay Co.

*Thalictrum dasycarpum* Fisch. and Lall.

Prairie Meadow Rue

Wooded slopes along the Little Sioux River at Peterson (5,051); prairie one mile southeast of Gillett Grove (5,055), wet meadow, south of Lost Island Lake Outlet (2,075 and 2,076), Clay Co.; wet meadow five miles east of Ruthven (2,069), prairie, Johnson's Slough (11,351), Palo Alto Co. Frequent.

#### MENISPERMACEAE (Moonseed Family)

*Menispermum canadense* L.

Moonseed

Hillside thicket along the Little Sioux River at Gillett Grove (880), Clay Co. Common along lake banks throughout the region.

#### BERBERIDACEAE (Barberry Family)

*Berberis vulgaris* L.

European Barberry

Bank of Lost Island Lake, Palo Alto Co.

*Caulophyllum thalictroides* (L.) Michx.

Blue Cohosh

Rich woods along the Little Sioux River at Peterson (947, 5,074 and 10,031), woods at Gillett Grove (926), Clay Co.

#### PAPAVERACEAE (Poppy Family)

*Sanguinaria canadensis* L.

Bloodroot

Infrequent on wooded ridges and slopes.

#### FUMARIACEAE (Fumitory Family)

*Dicentra cucullaria* (L.) Bernh.

Dutchman's Breeches

Wooded slopes along rivers and around lake banks. Uncommon.

*Corydalis aurea* Willd.

Golden Corydalis

Common among roadsides and sandy fields.

#### CRUCIFERAE (Mustard Family)

*Arabis dentata* T. & G.

Toothed Rock Cress

Rocky slopes and hillsides along the Little Sioux, Peterson (896), Clay Co.

*Arabis hirsuta* (L.) Scop.

Hairy Rock Cress

Dry upland prairie about five miles north and one mile east of Lost Island Lake (11,255), Palo Alto Co.

*Barbarea vulgaris* R. Br.

Winter Cress

Along highways. Infrequent.

*Berteroa incana* (L.) D.C.

Hoary Alyssum

Cultivated field and roadside along Highway 18 west of the Little Sioux River east of Peterson (5,006), Clay Co.

- Brassica Kaber* (DC.) Wheeler var. *pinnatifida* (Stokes) Wheeler      Field Mustard  
 See Rhodora 40:308. 1938.  
*Brassica arvensis* (L.) Rab.  
 Five miles west of Ruthven (11,256), Clay Co. Emmetsburg, L.H. Pammel, (I.S.C. 98,454), Palo Alto Co. Fields and roadsides throughout the region. Frequent.
- Brassica juncea* L.      Smooth Mustard  
 West Bend, R.I. Cratty (I.S.C. 109,001).
- Brassica nigra* (L.) Koch      Black Mustard  
 Gillett Grove, L.H. Pammel, (I.S.C. 74,437), Clay Co.
- Brassica Napa* L.      Rape  
 Roadsides, escaped from cultivation. Occasional.
- Camelina sativa* Crantz.      False Flax  
 Emmetsburg. Bert L. Francis, (I.S.C. 93,965), Palo Alto Co.
- Capsella bursa-pastoris* (L.) Medic.      Shepherd's Purse  
 Widespread cultivated ground and neglected soil.
- Cardamine bulbosa* (Schreb.) B.S.P.      Bulbous Cress  
 Wet soil around a spring at Pickerel Run (11,258), Clay Co. Margin of a pond, pasture south of Mud Lake, (5,012); hanging bog five miles east of Ruthven (5,042); hanging bog swamp along the Des Moines River one and one-half miles southwest of Osgood (5,044), Palo Alto Co.
- Cardamine pennsylvanica* Muhl.      Pennsylvania Bitter-Cress  
 Low prairie along a ditch north of Elk Lake (5,013), Clay Co. Swamp along the Des Moines River one and one-half miles southwest of Osgood (5,043), Palo Alto Co.
- Dentaria laciniata* Muhl.      Toothwort  
 Sandy wooded slopes (7,038), Clay Co.
- Descurainia pinnata* (Walt.) Britton sub. sp. *brachycarpa* (Richards) Detling  
    Tansy Mustard  
 See Am. Midl. Nat. 22:509. 1939.  
*Sisymbrium brachycarpum* Richards.  
*Sisymbrium canescens* Nutt. var. *brachycarpum* (Richards) S. Wats.  
 Along the C. M. and S. P. R. R. north of Graettinger (4,099); roadside one mile south of Ruthven (5,039); eastern sandy shore of Lost Island Lake (7,041 and 4,099), Palo Alto Co.
- Descurainia sophia* (L.) Webb and Prantl.      Hoary Hedge Mustard  
 See Am. Midl. Nat. 22:487. 1939.  
*Sisymbrium Sophia* L.  
*Sophia Sophia* (L.) Brit.  
 Ten miles south of Spencer (11,254), Clay Co. Alfalfa field west of Electric Park near the Lost Island Lake School two miles north of Ruthven (4,096); pasture at Electric Park two miles east of Ruthven (4,097), Palo Alto Co. Frequent in this region.
- Diplotaxus muralis* (L.) DC.      Wall Rocket  
 Roadside five miles east of Peterson (5,003), Clay Co. M. and St. L. R. R. station at Ruthven (5,001), Palo Alto Co., roadsides and fields. Infrequent.
- Draba reptans* (Lam.) Fernald.      Whitlow Grass  
 Rhodora 36:368. 1934.  
*D. caroliniana* Walt.  
 Gravel pit at the west border of Clay Co., Peterson Twp., Sec. 31; one mile north of Graettinger gravel pit (7,007), Palo Alto Co.
- Erysimum cheiranthoides* L.      Wormseed Mustard  
 In woods west of Gillett Grove (5,041); west bank of Round Lake (5,007), Clay Co. Shady south bank of Lost Island Lake (5,011), Palo Alto Co.



- Hesperis matronalis* L. Dame's Rocket  
Local along the south border of Lost Island Lake, on Babcock Farm, escaped from cultivation (9,600), Palo Alto Co.
- Lepidium campestre* (L.) R. Br. Field Cress  
Becoming frequent along roadsides and in fields.
- Lepidium draba* L. Hoary Cress  
Occasional along roadsides.
- Lepidium densiflorum* Schrad. Apetalous Pepper Grass  
*L. neglectum* Thell.  
*L. apetalum* of auth., not Willd.  
Frequent in cultivated fields and neglected areas.
- Lepidium virginicum* L. Virginia Pepper Grass  
Common. Gardens, cultivated fields and roadsides.
- Rorippa islandica* (Oed. ex Murr.) Borbás var. *microcarpa* (Regel) Fernald, Rhodora 42: 271. 1940. Smooth Marsh Cress  
*Nasturtium palustre* DC. var. *microcarpum* Regel  
*Rorippa islandica* (Oed. ex Murr.) Borbás var. *fernaldiana*, Butters and Abbe in Rhodora 12: 28. 1940.  
*Radicula palustris* DC. of manuals.  
Growing on the dry bed of Mud Lake north side (4,092); mud of a dried pond, Outlet of Lost Island Lake (4,093), Clay Co. Frequent.
- Rorippa islandica* (Oed. ex Murr.) Borbás var. *hispida* Butters and Abbe Hairy Marsh Cress  
See Rhodora 42: 26. 1940.  
*Rorippa palustris* (L.) Bess.  
*Radicula palustris* of Am. auth. not Moench.  
*Roripa hispida* (Desv.) Brit.  
*Radicula palustris* var. *hispida* (Desv.) Rob.  
Seedlings growing on the floodplain of the Little Sioux River (4,091), Clay Co.  
In water of a pond near the mouth wooded border of Mud Lake near a Crataegus grove (5,000 and 5,000a); around the margin of a cornfield pond east of Lost Island Lake (11,267), Palo Alto Co. Common along ditches in ponds and cultivated fields.
- Rorippa sinuata* (Nutt.) Hitchc. Spreading Yellow Cress  
*Radicula sinuata* (Nutt.) Greene  
Moist soil, on the bank of the Little Sioux River at Gillett Grove (5,004), Clay Co.
- Sisymbrium altissimum* L. Tall Hedge Mustard  
Just east of the entrance to Dickens, along Pickerel Run. Gravelly bank (4,098), Clay Co. West Bend, L. H. Pammel, (I.S.C. 96,057), Palo Alto Co.
- Sisymbrium officinale* (L.) Scop. var. *leiocarpum* DC. Hedge Mustard  
Common along roadsides, barnyards, fencerows and waste places.
- Thlaspi arvense* L. Penny Cress  
Along roadsides at Gillett Grove (5,050); along railroad track one-fourth mile east of Peterson (5,036), Clay Co. Becoming frequent in fields and along roadsides in Palo Alto Co.

## CAPPARIDACEAE (Caper Family)

- Polanisia graveolens* Raf. Small-flowered Clammy Weed  
See Pflanzenfamilien 17b: 215. 1936.  
*Cleome graveolens* (Raf.) Schultes  
Northeast sandy shore of Lost Island Lake (11,238), Palo Alto Co.
- Polanisia trachysperma* T. & G. Large-flowered Clammy Weed  
See Pflanzenfamilien 17b: 215. 1936.  
*Cleome trachysperma* (Torr. and Gray.) Pax and K. Hoffm.  
Gravelly sandbank on the northeast shore of Lost Island Lake.

## CRASSULACEAE (Orpine Family)

*Penthorum sedoides* L.

Ditch Stone Crop

Wet ground along the northeast margin of Elk Lake (5,079); two miles north and two miles east of Spencer in wet meadows along an oxbow cut-off of Meadow Creek (10,168), Clay Co. Five miles east of Ruthven around ponds in the prairie south of Highway 18, Palo Alto Co. General around shallow bodies of water.

## SAXIFRAGACEAE (Saxifrage Family)

*Heuchera richardsonii* R. Br. var. *grayana* Rosendahl, Butters and Lakela

Rhodora 35:117. 1933

Alum Root

*H. hispida* of auth., not Pursh

On dry open hillsides in a pasture near Gillett Grove (5,077); gravelly hill in cemetery at Dickens (10,139), Clay Co. Highland cemetery two miles east of Lost Island Lake, Palo Alto Co. Infrequent on dry prairie.

*Parnassia glauca* Raf.

Grass of Parnassus

See *Bartonia* 17:18. 1935.*Parnassia caroliniana* Michx.

Marshy zone in a hanging bog along the Little Sioux River (8,041), Clay Co. Hill-top bog and wet prairie in vicinity of spring outcrops, five miles east of Ruthven (267), Palo Alto Co. Rare except in hanging bogs.

*Ribes americanum* Mill.

Wild Black Currant

*R. floridum* L'Her.

One mile south of Round Lake along the roadside (10,144), Clay Co. Hanging bog along the west side of the Des Moines River one and one-half miles southwest of Osgood (878); bank of Lost Island Lake at Lost Island State Park (10,145), Palo Alto Co. Common around lake banks and wet roadsides.

*Ribes missouriense* Nutt.

Wild Gooseberry

*Ribes gracile* Michx.*Grossularia missouriensis* (Nutt.) Cov. and Brit.

Slopes of open woods along the Little Sioux River one mile west of Gillett Grove (924); on the large Island in Outlet of Lost Island Lake (9,526), Clay Co. Lost Island State Park, Lost Island Lake; L. H. Pammel, (I.S.C. 98,859 and 98,813), Palo Alto Co. Common in open woods and along lake banks.

*Ribes cynosbati* (L.) Mill.

Prickly Gooseberry

Wooded hillsides along the Little Sioux River one-half mile west of Peterson (940 and 10,146). Infrequent, but found on rocky woods or on floodplains.

## ROSACEAE (Rose Family)

*Agrimonia gryposepala* Wallr.

Agrimony

*A. hirsuta* Bick.

Dry slopes Dewey's Pasture (947 and 10,461); on the south bank of Dan Green Slough (12,201), Clay Co. Roadside at Electric Park near Lost Island Lake (10,460), Palo Alto Co.

*Amelanchier arborea* (Michx. f.) Fernald Rhodora 43:563. 1941.

Juneberry

*A. canadensis* sensu Wiegand in Rhodora 14:150. 1912.

About five miles north of Emmetsburg (7,576), Palo Alto Co. Occasional.

*Amelanchier humilis* Wiegand var. *exserrata* Nielson Am. Midl. Nat. 22:177. 1939.

Low Juneberry

Border of upland, dry woods along the Little Sioux River. Low shrub reaching 6 feet in height when growing among trees. (7,577), Clay Co.

*Crataegus calpodendron* (Ehrh.) Medic.

Growing on the floodplain of the Little Sioux River on the east side of the driveway into Wanata State Park (11,052 and 11,038), Clay Co. Infrequent.

*Crataegus chrysocarpa* Ashe

Round-leaved Thorn

N. Car. Agr. Col. Bull. 175:110. 1900.

- See Ann. list of plants  
 N.Y. State Mus. Bul. 254. 1924.  
*C. rotundifolia* (Ehrh.) Moench.  
 Along the fencerow of the road north of the Lost Island Lake School (11,014, 11,014a and 11,015), Palo Alto Co. Occasional Shores, open woods or fencerows.
- Crataegus mollis* (T. & G.) Scheele Woolly Thorn  
 In ravines, open woods and along floodplains of streams. Frequent.
- Crataegus punctata* Jaquin Dotted Thorn  
 Floodplain of a small stream tributary to the Little Sioux River, Adams Farm two and one-half miles southwest of Gillett Grove (11,046), Clay Co. Infrequent.
- Crataegus succulenta* Schrad. Long-spined Thorn  
*C. neofluviatilis* Ashe  
*C. macracantha* Lodd. var. *neofluviatilis* Ashe  
*C. ensifera* Sarg.  
 At the north edge of Ruthven along Highway 341 (9,466); two miles south of Ruthven on the west side of Virgin Lake on the Rice Farm (9,479), Palo Alto Co.
- Crataegus succulenta* Schrad. var. *pertomentosa* (Ashe) Palmer Prairie Thorn  
*C. pertomentosa* Ashe  
*C. campestris* Britton  
 A cluster of slender trees growing along the shaded bank of a stream tributary to the Little Sioux River, Adams Farm two and one-half miles southwest of Gillett Grove (11,109, 11,023, a, b, and c); along the north windswept shore of Mud Lake near a fringe of bur oak trees (11,016), Clay Co. Along the rocky east bank of Lost Island Lake. Bushy trees growing in openings in bur oak woods (11,045), Palo Alto Co. Infrequent.
- Fragaria vesca* L. Wood Strawberry  
 Open woodland slopes along the Little Sioux River, Wanata State Park, Peterson (10,043), Clay Co.
- Fragaria vesca* L. var. *americana* Porter American Wood Strawberry  
 Open woods along the Little Sioux River one mile west of Gillett Grove (930), Clay Co.
- Fragaria virginiana* Duchesne Virginia or Scarlet Strawberry  
 Common in open woods along roadsides, and prairies.
- Fragaria virginiana* Duchesne var. *illinoiense* (Prince) A. Gray Wild Strawberry  
 Open woods, slopes along the Little Sioux River, one mile west of Gillett Grove (935), Clay Co.; openings around wooded south margin of Lost Island Lake in Lost Island State Park (11,293), Palo Alto Co.
- Geum canadense* Jacq. White Avens  
 Wooded slopes along the Little Sioux River one mile west of Gillett Grove (10,463), Clay Co.; shaded bank of Lost Island Lake (9,468 and 9,488), Palo Alto Co. Frequent in woods.
- Geum laciniatum* Murr. var. *trichocarpum* Fern. Rough Avens  
 See Rhodora 37:293. 1935.  
*G. virginianum* L.  
 Open woodland one mile west of Gillett Grove (10,464), Clay Co.
- Malus ioensis* (Wood) Bailey Iowa Crab Apple  
*Pyrus ioensis* (Wood) Britton  
 Edge of woods, along roadside south of Peterson (913), Clay Co. East rocky bank of Lost Island Lake, single column (10,481), roadside south of Lost Island State Park (10,482), Palo Alto Co. Rare.
- Malus pumila* Mill. Common Apple  
 At the base of a hill in woodland along the Little Sioux River at Gillett Grove (10,483), Clay Co.

- Malus soulardi* (Bailey) Britton Soulard Crab  
*M. ioensis* Brit. x *M. pumila* Mill.  
 Roadside bank east of Lost Island Lake (9,478 and 10,496), Palo Alto Co. Not infrequent in this region.
- Potentilla arguta* Pursh Prairie Cinquefoil  
 Rocky prairie in cemetery on Dickens, also in Dewey's Pasture, Clay Co.; high prairie about four miles north of Lost Island Lake, Palo Alto Co. Not common, present in dry upland prairie.
- Potentilla norvegica* L. var. *hirsuta* (Michx.) Lehm. Rough Cinquefoil  
 See *Rhodora* 28:213-14. 1926.  
*Potentilla monspeliensis* L.  
 Roadside west of Spencer (5,093), Clay Co.; south beach of Lost Island Lake (10,453); pond bed south of Lost Island State Park (454), Palo Alto Co.
- Potentilla palustris* (L.) Scop. Marsh Cinquefoil  
 In shallow water of a grassy marsh along the margin of the Outlet of Lost Island Lake (10,452), Clay Co. Infrequent.
- Potentilla paradoxa* Nutt. Bushy Cinquefoil  
 Sandy beach, sandy south shore of Lost Island Lake (10,453 and 10,458), sandy gravelly east shore of Lost Island Lake (11,283), Palo Alto Co.
- Potentilla rivalis* Nutt. var. *millegrana* (Engelm.) Wats. Diffuse Cinquefoil  
 Meadows, borders of ponds and swamps.
- Potentilla rivalis* Nutt. var. *pentandra* (Engelm.) Wats. Five-stamened Cinquefoil  
 Meadows, borders of ponds and swamps.
- Prunus americana* Marsh. American Wild Plum  
 Widespread, occurring at the edge of woods, roadside, fencerows, and banks of lakes.
- Prunus serotina* Ehrh. Wild Black Cherry  
 Occurring along roadsides and in low woods. Occasional.
- Prunus virginiana* L. Choke Cherry  
 Common along lake banks, margins of upland woods.
- Rosa arkansana* Porter and Coulter Syn. Fl. Co. 38:1874. Wild Prairie Rose  
 Bot. Gaz. 96:256. 1934.  
*R. heliophila* Greene  
*R. pratincola* Greene  
*R. suffulta* Greene  
 Widespread and abundant, open prairie, roadsides, grain fields and pastures.
- Rosa blanda* Aiton Smooth or Meadow Rose  
 See Bot. Gaz. 96:250. 1934.  
 Common at margin of woods, hedgerows and lake banks.
- Rosa rubiginosa* L. Mant. 2:564. 1771. Sweet Brier Rose  
*R. eglanteria* Mill.  
 Dict. Ed. 8. No. 4. 1768, not L.  
 About two and one-half miles east of Lost Island Lake School along the roadside escaped from cultivation and naturalized (11,518), Palo Alto Co.
- Rubus idaeus* L. var. *aculeatissimus* (C. A. Mey.) Regel and Tiling. Red Raspberry  
 Emmetsburg, L.H. Pammel (I.S.C. 94,351), Clay Co. L.H. Pammel, (I.S.C. 9,778), Palo Alto Co. Infrequent.
- Rubus occidentalis* L. Black Raspberry  
 Open woodland along the slopes of the Little Sioux River one mile west of Gillett Grove (10,493), Clay Co. L.H. Pammel (I.S.C. 97,783), Palo Alto Co. Frequent in woods and hedgerows.

*Spiraea alba* Du Roi

Western Meadow Sweet

*Spiraea salicifolia* of auth., in part, not L.

Margin of pond in Dewey's Pasture (10,494), Clay Co. Four miles east of Lost Island Lake School (9,800), Palo Alto Co.

## LEGUMINOSAE (Bean Family)

*Amorpha canescens* Pursh

Lead Plant

High prairie hills, one mile east of Peterson (908), Clay Co. Prairie west of Lost Island Lake (4,023); east of Lost Island Lake (4,025); five miles east of Ruthven (11,322), Palo Alto Co. Common in upland prairie and roadsides.

*Amorpha canescens* Pursh forma *glabrata* Fassett

High prairie five miles east of Ruthven (11,322), Palo Alto Co.

*Amorpha fruticosa* L.

False Indigo

Spring along Pickerel Run (4,052), marsh between Mud and Trumbull Lake (6,010), Clay Co. Near the inlet on the west side of Lost Island Lake (7,028); sandy shore of Silver Lake on the northeast bank (4,056), Palo Alto Co.

*Amorpha fruticosa* L. var. *emarginata* Pursh

Emarginate False Indigo

In a marshy area of a hanging bog south of the bridge over the Des Moines River west of Osgood (4,053), Palo Alto Co.

*Amorpha nana* Nutt.

Dwarf False Indigo

*Amorpha microphylla* Pursh

Prairie roadside eight miles north of Ruthven (9,905), Clay Co. Prairie in the west-central half of the Protestant Cemetery at Ruthven (9,357), Palo Alto Co. Rare.

*Amphicarpa bracteata* (L.) Fern. var. *comosa* (L.) Fern.

Wild Hog Peanut

Rhodora 35:276. 1933; 39:318. 1937.

*A. pitcheri* (T. & G.)*Glycine comosa* L.*Falcata pitcheri* (T. & G.) Ktze.*A. bracteata* (L.) Fern. var. *Pitcheri* Fassett

On a bank bordering the south side of Dan Green Slough (4,058), Clay Co. Woods along the Des Moines River south of Graettinger (4,059), Palo Alto Co.

*Apios americana* Medic.

Ground Nut Wild Bean

See Rhodora 13:50. 1911.

*Apios tuberosa* Moench.

Bank around oxbow cutoff, two miles northeast of Spencer (4,043), bank of Dan Green Slough, Clay Co. Wooded bank of Lost Island Lake (4,044), Palo Alto Co. Infrequent.

*Astragalus canadensis* L.

Canada Milk Vetch

Prairie knolls Dewey's Pasture (6,004), Clay Co.; West Bend (I.S.C. 96,004), Palo Alto Co. Frequent.

*Astragalus caryocarpus* Ker.

Ground Plum

Common on gravelly hilltops or flat upland prairie.

*Astragalus goniatus* Nutt.

Purple Milk Vetch

See N.A. Flora 24:pt. 7:451. 1929.

*A. hypoglottis* Richardson, not L.*A. agrestis* M.E. Jones, not Doug.

On an elevation about the center of Dewey's Pasture (6,005, 9,345 and 11,305), Clay Co. Level prairie along a RR track parallel with Highway 17; about one mile north of Graettinger (4,046 and 10,052), Palo Alto Co.

*Baptisia leucophaea* Nutt.

Large-bracted Wild Indigo

*B. bracteata* of auth., not (Muhl.) Ell.

Prairie hillsides northeast of Gillett Grove (4,066), Clay Co. Railroad track one mile north of Graettinger (4,047); upland prairie five miles east of Ruthven (4,048); Highland Cemetery two miles east of Lost Island Lake (9,348), Palo Alto Co.

- Cassia fasciculata* Michx. Partridge Pea  
*C. chamaecrista* of auth: not L.  
*Chamaecrista fasciculata* (Michx.) Greene  
 Moist prairie five miles east of Ruthven (4,067 and 4,068), Palo Alto Co.
- Dalea alopecuroides* Willd. Slender Dalea  
 See Contr. Gray Herb. 65:17. 1922.  
*Parosela leporina* (Ait.) Rydb.  
 Sandy south shore of Round Lake (4,051), Clay Co.
- Desmodium glutinosum* (Muhl. ex. Willd.) Wood Pointed-leaved Trefoil  
 See Rhodora 44:279. 1942.  
*D. acuminatum* (Michx.) DC.  
 Wooded island in Virgin Lake (4,080) Palo Alto Co. Wooded hillsides bordering the Little Sioux River (4,081), Clay Co. Infrequent.
- Desmodium bracteosum* (Michx.) DC. var. *longifolium* (T. & G.) Rob. Large-bracted Tick-trefoil  
 One mile south of Peterson in Wanata State Park, wooded slopes along the Little Sioux River, (9,930), Clay Co.
- Desmodium canadense* DC. Canadian or Showy Trefoil  
 Prairie one mile west of Ruthven along the railroad track (4,084); roadside along Highway 314 between Ruthven and the Lost Island Lake School (4,083), Palo Alto Co.
- Desmodium illinoense* A. Gray Illinois Tick-trefoil  
 About one mile east and five miles south of Ruthven, prairie roadside (9,931), Palo Alto Co.
- Glycyrrhiza lepidota* (Nutt.) Pursh Wild Liquorice  
 Common on prairie roadsides and grassy pastures.
- Gymnocladus dioica* (L.) Koch Kentucky Coffee Bean  
 Wooded ravine in Wanata State Park along the Little Sioux River (9,938), Clay Co. Lost Island Lake, L.H. Pammel (I.S.C. 98,804), Palo Alto Co.
- Lathyrus ochroleucus* Hook. Cream-colored Vetch  
 Openings in wooded stops along the Little Sioux River (10,026), Clay Co.
- Lathyrus palustris* L. Marsh Vetch  
 Prairie along Highway 17 and the railroad track one mile north of Graettinger (4,078), Palo Alto Co.
- Lathyrus venosus* Muhl. var. *intonsus* Butters and St. John Veiny Vetch  
 Rhodora 19: 158. 1917.  
 About three and one-half miles west of Ruthven and one mile north of Highway 18, along a willow hedge (11,315), Clay Co. Dry roadside at edge of woods east of Virgin Lake (4,003); on level to sloping prairie west of Ruthven Cemetery (4,062); Hansen Prairie five miles east of Lost Island Lake (4,061 and 4,064), Palo Alto Co.
- Lespedeza capitata* Michx. Round-headed Bush Clover  
 Frequent to abundant in upland prairie.
- Medicago lupulina* L. Black Medic  
 Roadside between Ruthven and Emmetsburg (4,041); gravelly knoll, edge of gravel pit, Silver Lake (4,050); growing in blue grass, Lost Island State Park (11,323), Palo Alto Co.
- Melilotus alba* Desr. White Sweet Clover  
 Common along roadsides, railroad tracks and invading virgin prairie in wet seasons.
- Melilotus officinalis* (L.) Lam. Yellow Sweet Clover  
 Not infrequent in fields or on roadsides.



- Petalostemum candidum* Michx. White Prairie Clover  
Frequent on moist prairie slopes.
- Petalostemum purpureum* (Vent.) Rydb. Purple Prairie Clover  
Frequent on dry prairie or on eroding roadsides. Frequent.
- Psoralea argophylla* Pursh Silvery-leaved Psoralea  
Hill east of cemetery Dickens (4,045), Clay Co. Upland prairie five miles east of Ruthven (4,032), Palo Alto Co. Infrequent.
- Psoralea esculenta* Pursh Pomme de terre or Indian Breadfruit  
Tops of high hills one mile east of Peterson (904); prairie along railroad track about two miles east of Ruthven, Clay Co. Five miles east of Ruthven, in high prairie south of the viaduct (5,088), Palo Alto Co. Infrequent but recurrent on prairie knolls.
- Trifolium hybridum* L. Alsike Clover  
Occurring along roadsides and pastures. Naturalized.
- Trifolium pratense* L. Red Clover  
Roadsides, fields, naturalized.
- Trifolium procumbens* L. Hop-Clover or Tre-foil  
Spencer, W. A. Posey (I.S.C. 77,916), Clay Co. Lawn of Mrs. B. M. Stanton, Ruthven, (6,008), Palo Alto Co.
- Trifolium repens* L. Dutch or White Clover  
Common along roadsides, fields and pastures.
- Vicia americana* Muhl. American Vetch  
Four miles south of Everly along a branch of the Ocheydan River (915) and (4,072), Clay Co. Hughes Prairie two miles north of Lost Island Lake (4,075); grassy bank south of Lost Island Lake State Park (4,076); prairie along the railroad track north of Graettinger (10,025), Palo Alto Co. Frequent.
- Vicia americana* Muhl. var. *truncata* (Nutt.) Brewer Truncate-leaved American Vetch  
Low prairie east of Mud Lake (4,071), Clay Co.; moist black soil Hughes prairie (4,070), Palo Alto Co.

## LINACEAE (Flax Family)

- Linum sulcatum* Riddell Wild Flax  
Dry bank along Pickerel Run (10,065); prairie hillside, two miles west of Gillett Grove (1,027), Clay Co. Upland prairie five miles east of Ruthven (10,066), Palo Alto Co. Frequent.

## OXALIDACEAE (Oxalis Family)

- Oxalis corniculata* L. Creeping Yellow Wood Sorrel  
See Rhodora 27:120. 1925.  
*O. repens* Thunb.  
*Zanthoxalis corniculata* (L.) Small  
Fields and waste ground. Common.
- Oxalis europea* Jord. var. *bushii* (Small) Wiegand Lady's Sorrel  
Rhodora 27: 134. 1925.  
Open dry woods along the Little Sioux River at Gillett Grove (929), two miles north and two miles east of Spencer (10,076), eroded pasture at the entrance to Dickens (10,077), Clay Co.
- Oxalis europaea* Jord. f. *pilosella* Wiegand  
Rhodora 27:134. 1925.  
Vicinity of Lost Island Lake (11,476), Palo Alto Co.
- Oxalis stricta* L. Upright Yellow Wood Sorrel  
Woods, prairies and waste places. Common oxalis.

*Oxalis violacea* L.

Purple Sorrel or Wood Sorrel

Rocky open woods or prairies.

## GERANIACEAE (Geranium Family)

*Geranium maculatum* L.

Wild Cranesbill

Open woodland, hills along the Little Sioux River in Wanata State Park in Peterson (10,048), Clay Co.

## RUTACEAE (Rue Family)

*Xanthoxylum americanum* Mill.

Prickly Ash

Open woods one mile west of Gillett Grove (10,072); thickets along the edge of woods along the Little Sioux River at Peterson (10,037), Clay Co. Upland woods along the Des Moines River (10,083), Palo Alto Co.

## POLYGALACEAE (Milkwort Family)

*Polygala verticillata* L.

Whorled Milkwort

Dry prairie knolls, Hughes Prairie about two miles north of Lost Island Lake (10,075), Palo Alto Co.

## EUPHORBACEAE (Spurge Family)

*Acalypha rhomboidea* Raf.

Three-seeded Mercury

See Rhodora 39:16. 1937.

*A. virginica* sensu Weatherby, Rhodora 29:194. 1927 not L. (1,753).

On the floodplain of the Little Sioux River at Peterson (6,026); one mile east of Peterson (6,027), Clay Co. Sandy north shore of Silver Lake (6,041), Palo Alto Co.

*Euphorbia corollata* L.

Flowering Spurge

Common along roadsides and in prairie.

*Euphorbia dictyosperma* Fisch. and Mey.

Reticulate-seeded Spurge

*Tithymalus missouriensis* (Norton) Small*Tithymalus arkansanus* Engelm. and Gray*Galarrhoeus missouriensis* (Norton) Rydb.*Galarrhoeus arkansanus* Engelm. and Gray

Roadside along Highway 18 just west of the Little Sioux about four miles east of Spencer (9,311), Clay Co.

*Euphorbia glyptosperma* Engelm.

Ridge-seeded Spurge

A gravelly hill at the entrance to Dickens along Pickerel Run (6,043); dry hillside one mile west of Peterson (6,043), Clay Co. Sandy northeast shore of Lost Island Lake (6,039 and 6,042); dry upland field one-half mile west of Virgin Lake (6,037), Palo Alto Co. This plant assists as a soil binder in periods of drought when the blue grass is withered.

*Euphorbia heterophylla* L.

Various-leaved Spurge

On the sandy south shore of Lost Island Lake near the inlet under willows. When growing in the shade, the base of the bracts is white; in sunlight red (6,028), Palo Alto Co.

*Euphorbia supina* Raf.

Spotted Spurge

See Rhodora 43:254. 1941.

*E. maculata* sensu Torrey Fl. State N. Y., 2:176. 1843 and other Am. auth.

Common on roadside banks, in pastures and waste places.

*Euphorbia maculata* L.

Upright Spotted Spurge

See Rhodora 43:143. 1941.

*E. preslii* Guss.*E. nutans* Lag.

Sandy northeast shore of Lost Island Lake (6,030), Palo Alto Co. Frequent throughout the region.

*Euphorbia esula* L.

Leafy Spurge

Spencer, Henry Schroeder, I.S.C. 117,783), Clay Co.

## CALLITRICHACEAE (Water Starwort-Family)

*Callitriche heterophylla* Pursh.

Water Starwort

About seven miles north of Ruthven, in Dewey's Pasture in standing water at the dam near the entrance (9,558), Clay Co. Five miles east of Ruthven in a pasture one-fourth mile south of the viaduct in Highway 18, growing in water of a pond (5,084), Palo Alto Co.

## ANACARDIACEAE (Cashew Family)

*Rhus glabra* L.

Smooth Sumach

Common, roadside banks and border or woods.

*Rhus typhina* L.

Staghorn Sumach

*R. hirta* Sudw.

Roadside, Sec. 27, Lost Island Twp. (7,161) Palo Alto Co.

*Rhus toxicodendron* L.

Poison Ivy

See Ann. Mo. Bot. Gard. 24:419. 1937; Rhodora 43:597. 1941.

*Toxicodendron radicans* (L.) Ktze.

Common, open woods, roadside banks and borders of lakes.

## CELASTRACEAE (Bittersweet Family)

*Celastrus scandens* L.

Bittersweet

Occasional throughout the region on eroding banks and open woods.

*Evonymus atropurpureus* Jacq.

Wahoo or Burning Bush

Wooded flood plain of the Little Sioux River one mile west of Gillett Grove (5,073, 10,069 and 10,071), Clay Co.

## STAPHYLEACEAE (Bladdernut Family)

*Staphylea trifolia* L.

Bladdernut

Along bases of slopes of hills bordering the Little Sioux River at Wanata State Park (5,069), Clay Co. Uncommon.

## ACERACEAE (Maple Family)

*Acer negundo* L.

Box Elder

Two miles, south of Gillett Grove, roadside (872), Clay Co.. Wooded hillside along the west bank of the Des Moines River (870), Palo Alto Co. Common in open woods, low ground.

*Acer nigrum* Michx.

Black Maple

Slopes of wooded hills, along a tributary of the Little Sioux River of Adams Farm (869 and 871), Clay Co. One and one-half miles southwest of Osgood along the base of a hill bordering a hanging bog (7,026), Palo Alto Co. Infrequent in this region but present in rich woods along slopes and base of hills.

*Acer saccharinum* L.

Silver or Soft Maple

Common along banks of streams and around borders of lakes.

## BALSAMINACEAE (Touch-me-not Family)

*Impatiens biflora* Watt.

Spotted Touch-me-not or Jewelweed

Moist shady flood plain along the Little Sioux River, Wanata State Park (898), spring at Pickerel Run, Dickens (10,080), Clay Co. South side of Lost Island State Park, Palo Alto Co. Common in wet woods, vicinity of springs and along wet lake banks in open exposures.

*Impatiens pallida* Nutt.

Pale Touch-me-not

Abundant in Wanata State Park (7,288), Clay Co. Occurring in wet woods. Infrequent, on wooded west shore of Lost Island Lake (7,289), Palo Alto Co.

## RHAMNACEAE (Buckthorn Family)

*Ceanothus ovatus* Desf.

Ovate-leaved New Jersey Tea

High, gravelly hilltop one mile east of Peterson (10,153 and 10,170), Clay Co. Five miles south of Lost Island Lake, high prairie (10,169), Palo Alto Co. Infrequent on prairie slopes.

*Rhamnus cathartica* L.

Buckthorn

Roadside bank about 50 feet from the northeast shore of Virgin Lake, two miles south of Ruthven (10,154), Palo Alto Co.

## VITACEAE (Vine Family)

*Parthenocissus inserta* (Kern.) K. Fritsch

Low Virginia Creeper

*P. vitacea* Hitchc.

Climbing over shrubs in woods on Adams Farm in valley of the Little Sioux near Gillett Grove (879), Clay Co.

*Parthenocissus quinquefolia* (L.) Planch.

Virginia Creeper

*Psedera quinquefolia* (L.) Greene

East bank of Round Lake (10,008), Clay Co. L. H. Pammel (I.S.C. 97,732), Palo Alto Co. Common in woods and along lake shores.

*Vitis vulpina* L.

River-bank Grape

*V. riparia* Michx.

Abundant on lake banks, along rivers and fence rows.

## TILIACEAE (Linden Family)

*Tilia americana* L.

Basswood or Linden

*T. glabra* Vent.

Slopes and base of hills along the Little Sioux River, west of Gillett Grove (874), Clay Co. Slopes of low hills bordering the west fork of the Des Moines River, one mile southwest of Osgood (873), Palo Alto Co. Infrequent.

## MALVACEAE (Mallow Family)

*Abutilon theophrasti* Medic.

Velvet Leaf

Gillett Grove, L.H. Pammel, (I.S.C. 74,447), Clay Co. Becoming frequent in cultivated fields and gardens. Introduced from India.

*Malva neglecta* Wallr.

Common Mallow or Cheeses

See *Rhodora* 39:99. 1937.*M. rotundifolia* of auth., not L.

Gillett Grove L.H. Pammel (I.S.C. 74,443), Clay Co. Common in cultivated ground, barnyards and roadsides. Naturalized from Europe.

*Hibiscus trionum* L.

Flower-of-an-hour

Edge of cornfield at the west edge of Ruthven (9,394), Palo Alto Co. Common in gardens and cultivated ground.

## HYPERICACEAE (St. John's Wort Family)

*Hypericum canadense* L.

Canadian St. John's Wort

Around a pond at the crossroads west of Lost Island Lake (9,512), Clay Co. Not uncommon around ponds.

*Hypericum perforatum* L.

Common St. John's Wort

About two miles east of Lost Island Lake on a bank at Highland Cemetery (9,451); five miles south of Emmetsburg on Highway 17, roadside (11,357), Palo Alto Co. Infrequent.

## CISTACEAE (Rockrose Family)

*Helianthemum bicknellii* Fernald, *Rhodora* 21:36. 1919.

Rock Rose

*Helianthemum majus* Bicknell, not BSP.*Crocanthemum majus* (L.) Britton

Rocky, upland prairie on the east side of Medium Lake (7,460), Palo Alto Co.

## VIOLACEAE (Violet Family)

*Viola eriocarpa* Schw. var. *leiocarpa* Fernald and Wiegand  
Smooth-fruited Smooth Yellow Violet

Rhodora 23:275. 1922.

See Bull. Torr. Bot. Club 38:194. 1911.

*V. scabriuscula* Schwein, in part.

Wooded slopes, floodplains and lake banks throughout the region. The most common of the yellow violets.

*Viola missouriensis* Greene Missouri Violet  
Abundant locally, or occasional in low sandy woods of the region.

*Viola nephrophylla* Greene Northern Bog Violet  
In hanging bogs, abundant locally in this type of habitat.

*Viola papilionacea* Pursh Meadow or Hooded Blue Violet  
*V. obliqua* Pursh  
*V. domestica* Hill  
*V. pratensis* Green  
The most common violet in this area.

*Viola papilionacea* x *pedatifida* Brainerd  
Growing along the C.M. and St. P. railroad track four miles east of Ruthven on a bank.

*Viola pedatifida* Don. Prairie or Larkspur Violet  
*V. delphinifolia* Nutt.  
*V. indivisa* Greene  
The common violet of upland dry prairie. An ecological equivalent of the *V. pedata* L. var. *lineariloba* DC. found further south in similar locations.

*Viola pubescens* Ait. Downy Yellow Violet  
*V. pennsylvanica* Michx.  
Wooded hills one mile west of Gillett Grove along the Little Sioux River (10,257), Clay Co. Infrequent. Intergrades with *V. eriocarpa* Schwein var. *leiocarpa* (Fern.) Wiegand.

*Viola septentrionalis* Greene Northern Blue Violet  
See Violets of N.A. Vt. Exp. Sta. Bull. 224:44. 1921.  
Violaceae of Iowa. Stud. Nat. Hist. State Univ. Iowa 27:61. 1936.  
*V. macounii* Greene  
*V. subviscosa* Greene  
*V. fletcheri* Greene  
*V. nesiotia* Greene  
Moist open grassland (9,296), Clay Co.; occurs also in open woodland.

*Viola sororia* Willd. Woolly Blue Violet  
See Violets of N.A. Vt. Exp. Sta. Bull. 224:41. 1921.  
*V. cuspidata* Greene  
*V. dicksonii* Greene  
*V. nodosa* Greene  
*V. palmata* var. *sororia* (Willd.) Pollard  
Wooded lake shores. Stream valleys and floodplains. Frequent.

## LYTHRACEAE (Loose Strife Family)

*Lythrum alatum* Pursh Winged Loosestrife  
Edge of pond northwest of crossroads west of Lost Island Lake (9,406), Clay Co. About five miles east of Ruthven around a pond south of the viaduct over Highway 18, (9,407), Palo Alto Co. Frequent.

*Rotala ramosior* (L.) Koehne Toothcup  
Growing along the muddy north border of Medium Lake (8,610), Palo Alto Co.

## ONAGRACEAE (Evening Primrose Family)

- Circaea latifolia* Hill Enchanter's Night Shade  
 See Rhodora 19:87. 1917.  
*C. lutetiana* of Am. auth. not L.  
 Drywoods along the Little Sioux River, Wanata State Park, at Peterson (4,000), Clay Co. Common in rocky, dry woods.
- Epilobium coloratum* Haussk. Purple-leaved Willow Herb  
 Marshy border of the Outlet of Lost Island Lake northwest of Ruthven (10,097), Clay Co. Wet ground of a fen five miles east of Ruthven (10,098), Palo Alto Co.
- Epilobium densum* Raf. Narrow-leaved Willow Herb  
 Springy bank of Pickerel Run just east of Dickens (10,095). Clay Co. Hanging bog five miles east of Ruthven south of the viaduct over Highway 18 (10,094), Palo Alto Co. Infrequent in marshes.
- Epilobium glandulosum* Lehm. var. *adenocaulon* (Haussk.) Fernald Rhodora 20:34. 1918.  
 Northern Willow Herb  
*E. adenocaulon* Haussk.  
 Marshy margin of the outlet of Lost Island Lake (10,097); springy bank of Pickerel Run at Dickens (10,096), Clay Co. Marshy zone around a hanging bog five miles east of Ruthven (10,096); sandy beach south of Lost Island State Park, near the inlet of Lost Island Lake (10,099), Palo Alto Co.
- Ludvigia polycarpa* Short and Peter False Loosestrife  
 Five miles east of Ruthven in a pond south of the viaduct over Highway 18 (9,416), Palo Alto Co. Infrequent on the muddy borders or dry beds of ponds.
- Oenothera biennis* L. Evening Primrose  
 Five miles east of Ruthven in prairie (10,085), Palo Alto Co. Frequent in prairie or in waste areas.
- Oenothera parviflora* L. Northern Primrose  
 See Rhodora 26:4. 1924.  
*Oe. muricata* L.  
 Sandy border of Mud Lake in Dewey's Pasture (10,089), Clay Co. South beach of Lost Island Lake near Electric Park (10,101), Palo Alto Co.
- Oenothera serrulata* Nutt. Serrate-leaved Primrose  
*Meriolix serrulata* (Nutt.) Walp.  
 Gravelly prairies and roadsides (10,081), Palo Alto Co. Rare.

## HALORAGIDACEAE (Water Milfoil Family)

- Hippuris vulgaris* L. Mare's Tail  
 Marsh on the north side of Dewey's Pasture, in shallow water near the line fence (779 and 10,149), Clay Co.
- Myriophyllum spicatum* L. Water Milfoil  
 In two feet of water, silt bottom, Round Lake (711), Clay Co.; Johnson's Slough one mile east of Lost Island Lake (11,500), Palo Alto Co.

## ARALIACEAE (Aralia Family)

- Aralia nudicaulis* L. Wild Sarsaparilla  
 Moist, shaded slopes in oak-maple-linden woods, along the Little Sioux River (894 and 5,075), Clay Co.
- Aralia racemosa* L. Spikenard  
 Wooded hills along the Little Sioux River at Peterson (7,173), Clay Co. Margin of a bog along the Des Moines River (7,152), Palo Alto Co.
- Panax quinquefolium* L. Ginseng  
 In rich woods along the Little Sioux River at Wanata State Park (5,066), Clay Co.



## UMBELLIFERAE (Parsnip Family)

- Anethum graveolens* L. Dill  
Escaped from cultivation. Vacant lot, Ruthven, Palo Alto Co.
- Berula pusilla* (Nutt) Fernald Cut-leaved Water Parsnip  
See Rhodora 44:189. 1942.  
*Berula erecta sensu* Coville in Contrib. U. S. Nat. Herb. 4:115. 1893; not *Sium erectum* Hudson  
Marsh around a hanging bog along the West Fork of the Des Moines River one and one-half miles southwest of Osgood (10,433), Palo Alto Co.
- Cicuta bulbifera* L. Bulbous Water Hemlock  
Wet meadow along the bank of Pickerel Run (7,000 and 10,418), Clay Co. Tussock marsh near the Inlet of Lost Island Lake (10,417 and 10,419); marshy north side of the west bay of Virgin Lake (10,420), Palo Alto Co.
- Cicuta maculata* L. Water Hemlock  
Tussock marsh near the inlet of Lost Island Lake (10,419), Palo Alto Co. Not uncommon.
- Lomatium orientale* Coulter and Rose White-flowered Parsley  
See Bull. Torr. Bot. Club 69:244. 1942.  
*Cogswellia orientalis* Coult. and Rose  
*Pseucedanum villosum* Nutt.  
Common locally on gravelly hills along the C. & N. W. railroad track at the western border of Peterson Twp., Sec. 19, Clay Co. Appearing also around gravel pits.
- Cryptotaenia canadensis* (L.) DC. Honewort  
*Deringa canadensis* (L.) Kuntze  
Low woods along the Little Sioux River in Wanata State Park (10,416), Clay Co. Wooded slopes along the Des Moines River (10,427), Palo Alto Co.
- Daucus carota* L. Wild carrot, Queen Anne's Lace  
Frequent along roadsides and in fields. Introduced.
- Eryngium yuccifolium* Michx. Rattlesnake Master  
Upland or lowland virgin prairie, sometimes growing abundantly on the site of old haystacks.
- Heracleum lanatum* Michx. Cow Parsnip  
South of Peterson in low woods, Wanata State Park (10,414), Clay Co. Abundant locally.
- Osmorrhiza claytoni* (Michx.) Clarke Woolly Sweet Cicely  
Frequent on woodland slopes.
- Osmorrhiza longistylis* (Torr.) D.C. Smooth Sweet Cicely  
Wooded slopes along the Little Sioux River at Gillett Grove (928) and at Peterson (884), Clay Co.
- Osmorrhiza longistylis* (Torr.) D.C. var. *villicaulis* Fernald Hairy-stemmed Smooth Sweet Cicely  
Shady woodland along the Little Sioux River one mile west of Gillett Grove (10,426), Clay Co.
- Oxyopolis rigidior* (L.) Coult. and Rose Cowbane  
Wet meadow around marshes. Rare.
- Pastinaca sativa* L. Wild Parsnip  
Frequent along roadsides and in waste areas.
- Sanicula canadensis* L. var. *genuina* Fernald  
See Rhodora 42:467. 1940.  
*S. canadensis* L. Sp. Pl. 235 (1,53) in part.  
Upland slopes in oak-hickory woods near Peterson (893), Clay Co. Low woods,

along the Des Moines River below the bridge, one and one-half miles southwest of Osgood (10,432), Palo Alto Co.

*Sanicula gregaria* Bicknell Clustered Snakeroot

In maple-linden woods along the Little Sioux River in Wanata State Park (10,423), Clay Co. Lost Island Lake, L.H. Pammel, (I.S.C. 98,862), Palo Alto Co.

*Sanicula marylandica* L. Black Snakeroot

In maple-linden woods along the Little Sioux River in Wanata State Park, south of Peterson (10,424), Clay Co.

*Sium suave* Walt. Hemlock Water Parsnip

See Rhodora 17:131. 1915.

*Sium cicutaefolium* J.F. Gmel.

Marshy south shore of Mud Lake associated with *Sparganium eurycarpum* (10,428); marshy ground around an oxbow cutoff in Meadow Creek, four miles northwest of Spencer (10,429), Clay Co.

*Taenidia integerrima* (L.) Drude Yellow Pimpernel

Slopes of oak-hickory woods along the Little Sioux River, one mile west of Gillett Grove (10,422), Clay Co. On a roadside bank near the West Fork of the Des Moines River, four miles south of Graettinger (10,421), Palo Alto Co.

*Thaspium barbinode* (Michx.) Nutt. Hairy-jointed Meadow Parsnip

Wooded slopes along the Little Sioux River at Gillett Grove (11,439); and in Wanata State Park at Peterson (11,404), Clay Co. Five miles south of Graettinger on a gravelly bank along the roadside near the Des Moines River (10,430), Palo Alto Co.

*Zizia aurea* (L.) Koch Golden Alexander or Golden Meadow Parsnip

Wet meadow and upland prairie throughout the region. Frequent.

#### CORNACEAE (Dogwood Family)

*Cornus drummondii* Meyer Rough-leaved Dogwood

See Am. Midl. Nat. 27:261. 1942.

*C. asperifolia* Michx.

Borders of woods and open woods.

*Cornus alternifolia* L. Alternate-leaved Dogwood

On slopes of wooded hills along the Little Sioux River in Wanata State Park (5,068), Clay Co.

*Cornus obliqua* Raf. Kinnikinnik

*C. purpusi* Koehne

*C. amomum* of auth., in part, not Mill.

West bank of Mud Lake (10,446), Clay Co. South bank of Lost Island Lake near its inlet (10,447), Palo Alto Co.

*Cornus racemosa* Lam. Panicle Dogwood

*C. paniculata* L' Hér.

*C. foemina* of auth. not Mill.

Two miles southwest of Gillett Grove in a shrub colony on gravelly prairie hills (11,414), open woods in Wanata State Park along the Little Sioux River (10,444), Clay Co.

#### PRIMULACEAE (Primrose Family)

*Androsace occidentalis* Pursh Androsace

Gravelly banks, bare hills and gravel pits. Infrequent.

*Lysimachia ciliata* L. Fringed Loosetrife

See Pflanzenfam. IV. 237:276. 1905.

*Stemonema ciliatum* (L.) Raf.

Moist soil, which part of the season is submerged, bridge at west end of Lost Island Lake (11,418); wet meadow, adjoining an oxbow cutoff two miles north and two miles east of Spencer (10,156), Clay Co. West Bend, R.I. Cratty (I.S.C. 96,030), Palo Alto Co.

*Lysimachia quadriflora* Sims Linear-leaved Loosestrife  
*Steironema quadriflorum* (Sims.) Hitchc.  
 Wet soil, Dewey's Pasture (7,519), Clay Co. Around the margin of a hanging bog, five miles east of Ruthven (11,419), Palo Alto Co.

*Lysimachia thyrsiflora* L. Tufted Loosestrife  
 Three miles northwest of Ruthven in a grassy swamp in the outlet of Lost Island Lake (10,155), and (10,347), Clay Co. Bog along the Des Moines River one and one-half miles west of Osgood (7,575), Palo Alto Co.

#### OLEACEAE (Olive Family)

*Fraxinus nigra* Marsh. Black or Swamp Ash  
*F. sambucifolia* Lam.  
 Terrace along the West Fork of the Des Moines River, one and one-half miles west of Osgood; woodlot below the bridge over the river (856), Palo Alto Co.

*Fraxinus pennsylvanica* Marsh. var. *austini* Fernald, Rhodora 40: 452. 1938. Austin's Red Ash  
*F. campestris* Britton in part.  
 East bank of Silver Lake, (9,760 and 9,761), Palo Alto Co.

*Fraxinus pennsylvanica* Marsh var. *lanceolata* (Borkh.) Sargent Green Ash  
 See Rhodora 4:453. 1938.  
*F. lanceolata* Borkh.  
 The commonest ash in the region. Woodland slopes, lake banks and around dwellings. Used for groves.

#### GENTIANACEAE (Gentian Family)

*Gentiana andrewsii* Griseb. Bottle or Closed Gentian  
 Low meadow bordering the Outlet of Lost Island Lake (10,193), Clay Co. Low prairie five miles east of Ruthven (10,409 and 10,194); prairie along the railroad and highway north of Rodman (10,410), Palo Alto Co.

*Gentiana procera* Holm Smaller Fringed Gentian  
 Six miles south and two miles east of Dickens around a hanging bog in a pasture along the Little Sioux River (10,190), Clay Co. Five miles east of Ruthven opposite the viaduct in Highway 18, growing in the sedge zone of a hanging bog (10,188 and 10,191), Palo Alto Co.

*Gentiana puberula* Michx. Downy Gentian  
 Frequent on dry knolls or level prairie.

*Menyanthes trifoliata* L. var. *minor* Michx. Buck Bean  
 See Rhodora 31:198. 1929.  
*M. verna* Raf.

In water of a grassy swamp along the edge of Lost Island Lake outlet, two miles northwest of Ruthven (2,061), Clay Co. One mile east of Lost Island Lake in Johnson's Slough, (9,183 and 11,423), Palo Alto Co. Coot's nests were built in the shelter of the colonies in summer of 1939.

#### APOCYNACEAE (Dogbane Family)

*Apocynum androsaemifolium* L. Spreading Dogbane  
 Open woods along the Little Sioux River, one mile west of Gillett Grove (10,274), Clay Co.

*Apocynum cannabinum* L. Indian Hemp  
 Cultivated ground west of Barringer's Slough (4,002 and 10,740); common around the banks of Round Lake (10,273), Clay Co. Frequent.

*Apocynum cannabinum* L. var. *pubescens* (Mitchell) A. DC. Hairy Indian Hemp  
 See Ann. Mo. Bot. Gard. 17:122. 1930.  
 Also Ann. Mo. Bot. Gard. 23:159-168. 1936.  
*A. androsaemifolium* x *A. cannabinum*.  
 Growing in a wet roadside depression in open country near virgin prairie, five miles north of Lost Island Lake (7,532) Palo Alto Co.

*Apocynum sibiricum* Jacq.

Clasping-leaved Dogbane

The most common species in virgin prairie or in grazed pasture. Bordering ponds in Dewey's pasture, seven miles north of Ruthven.

#### ASCLEPIADACEAE (Milkweed Family)

*Acerates viridiflora* (Raf.) Eaton

Green Milkweed

Five miles east of Ruthven in upland prairie south of the viaduct in Highway 18 (9,370 and 10,287); sandy beach along the northeast bank of Lost Island Lake (10,286), Palo Alto Co.

*Acerates floridana* (Lam.) Hitchc.

Florida Milkweed

West Bend, R.I. Cratty, (I.S.C. 96,049), Palo Alto Co.

*Asclepias amplexicaulis* J.E. Smith

Clasping-leaved Milkweed

Dry, upland prairie five miles east of Ruthven (7,105).

*Asclepias incarnata* L.

Swamp Milkweed

Common in wet meadow around swamps, sloughs and lakes.

*Asclepias ovalifolia* Dec.

Oval-leaved Milkweed

Dry grassy knolls in Dewey's Pasture. Infrequent. (10,285) Clay Co. Prairie five miles east of Ruthven south of the viaduct in Highway 18 (10,284), Palo Alto Co.

*Asclepias speciosa* Torr.

Showy Milkweed

Prairie five miles east of Ruthven south of the viaduct in Highway 18 (10,284), Palo Alto Co. Recurrent in moist soil around ponds in Dewey's pasture, seven miles north of Ruthven (7,536), Clay Co.

*Asclepias sullivantii* Engelm.

Sullivan's Milkweed

Occurring in rich, moist, virgin, usually level prairie near ponds. Seen along roadside depressions and banks, but not in pastures or fields.

*Asclepias syriaca* L.

Field Milkweed

*A. cornuti* Dcne.

Common in cultivated fields and roadsides.

*Asclepias tuberosa* L.

Tuberous-rooted Milkweed

South of Trumbull Lake, along a grassy lane (9,362); prairie one mile southeast of Gillett Grove (10,279), Clay Co. Roadside north of Graettinger (10,277); prairie slopes, five miles east of Ruthven opposite the viaduct on Highway 18 (10,289), Palo Alto Co.

*Asclepias verticillata* L.

Whorled Milkweed

Pasture west of Trumbull Lake (9,371), Clay Co. Prairie at the left side of Highway 18 two miles east of Ruthven (10,276), Palo Alto Co.

#### CONVOLVULACEAE (Morning Glory Family)

*Convolvulus arvensis* L.

European Morning Glory

Frequent in gardens along railroad tracks and sometimes in fields.

*Convolvulus sepium* L.

American Morning Glory

On the bank of a drainage ditch about one and one-half miles south of Dan Green Slough (3,014); prairie three miles west of Ruthven adjacent to Highway 18 (3,034), Clay Co.

*Cuscuta coryli* Engelm.

Hazel Dodder

On the bank of Mud Lake on the north side near the bridge over road, twining on an aster (3,018), Clay Co.

*Cuscuta paradoxa* Raf.

Glomerate Dodder

On the northeast bank of Mud Lake near the bridge (3,015); in pasture between Trumbull and Round Lakes (3,017); on bank of oxbow cutoff two miles east of Spencer, growing on *Helianthus grosse serratus* (3,016), Clay Co.

*Cuscuta polygonorum* Engelm.

Smartweed Dodder

In Dewey's Pasture seven miles north of Ruthven on *Polygonum coccineum* (9,399); three miles east of Spencer on the floodplain of the Little Sioux (3,013), Clay Co.

*Ipomoea purpurea* (L.) Roth

Morning Glory

Occasional, growing in cornfields.

## POLEMONIACEAE (Phlox Family)

*Collomia linearis* Nutt.

Narrow-leaved Collomia

See Rhodora 23:288. 1921.

*Gilia linearis* (Nutt.) Gray

Dry hard soil near the M. & St. L. railroad station in Ruthven (10,000), Palo Alto Co.

*Phlox divaricata* L. var. *laphami* Wood

Blue Wood Phlox

See Barton 12:34. 1930.

*Phlox divaricata laphami* Clute

*Phlox laphami* Clute

Common in low woods and on shaded lake banks.

*Phlox pilosa* L. var. *fulgida* Wherry

Downy Prairie Phlox

See Barton 12:47. 1931.

Frequent on level or low prairie.

*Polemonium reptans* L.

Jacob's Ladder or Greek Valerian

Rich wooded slopes along the Little Sioux River at Wanata State Park, Peterson (5,081), sometimes growing in open prairie near the woods, Clay Co.

## HYDROPHYLLACEAE (Waterleaf Family)

*Ellisia nyctelea* L.

Ellisia

Alluvial or cultivated soil, low woods or in the open. Common.

*Hydrophyllum virginianum* L.

Virginia Waterleaf

Wooded slopes along the Little Sioux River one mile west of Gillett Grove (934); Wanata State Park south of Peterson (889), Clay Co. Along the north wooded shore of Lost Island Lake (9,316); in relatively open bur oak woods bordering the southwest margin of Mud Lake (3,026), Palo Alto Co.

## BORAGINACEAE (Borage Family)

*Lappula echinata* Gilibert

Stickseed

Common, neglected soil and pastures.

*Hackelia virginiana* (L.) I. M. Johnston

Virginia Stickseed or Beggars Lice

See Contr. Gray Herb. 68:43. 1923.

*Lappula virginiana* (L.) Greene

Under trees along the south border of Lost Island Lake (9,005), Palo Alto Co.

*Lithospermum angustifolium* Michx.

Narrow-leaved Puccoon

*L. linearifolium* Goldie

Frequent in prairie, pastures and along roadsides.

*Lithospermum canescens* (Michx.) Lehm.

Hoary Puccoon

Common on upland prairies.

*Onosmodium occidentale* Mack.

Western False Cromwell

Frequent on dry prairies.

## VERBENACEAE (Verbena Family)

*Verbena bracteata* Lag. and Rodr.

Bracted Vervain

See Ann. Mo. Bot. Gard. 20:204. 1933.

*V. bracteosa* Michx.

Fields, barnyards, roadsides, dry hard soil. Common.

- Verbena hastata* L. Blue Vervain  
Common along streams and around ponds in pastures. Frequent.
- Verbena rydbergii* Moldenke Rydberg's Verbena  
Rev. Sudam Bot. 4:19. 1937  
*V. stricta* x *V. hastata*  
Wet ground along Little Meadow Creek, one mile north and two miles east of Spencer (3,006); pasture across the road from Dewey's Pasture seven miles north of Ruthven (3,006), Clay Co. L.H. Pammel (I.S.C. 97,793) Palo Alto Co.
- Verbena stricta* Vent. Hoary Vervain  
Abundant in dry and overgrazed pastures, roadsides and uncultivated ground.
- Verbena urticaefolia* L. var. *leiocarpa* Perry & Fernald White Vervain  
Rhodora 38:441-43. 1936.  
Along the floodplain of the Little Sioux R. at Peterson (7,373), Clay Co. Wet soil around a hillside spring on the west side of the Des Moines River two miles west of Osgood (7,372), Palo Alto Co. L.H. Pammel (I.S.C. 98,810). Border of Lost Island Lake, Palo Alto Co.

## LABIATAE (Mint Family)

- Agastache nepetoides* (L.) Kuntze Catnip Giant Hyssop  
Open woodland north of Virgin Lake (9,095 and 9,096), Palo Alto Co. Along the shore of Round Lake opposite Trumbull Lake, Gillett Grove, L.H. Pammel, (I.S.C. 78,368), Clay Co.
- Agastache scrophulariaefolia* (Willd.) Kuntze Figwort Giant Hyssop  
Low open woodland along the Des Moines River (9,060), Palo Alto Co.
- Blephilia hirsuta* (Pursh) Benth. Hairy Blephilia  
Lost Island Lake, L. H. Pammel, (I.S.C. 98,846).
- Hedeoma hispida* Pursh Rough Pennyroyal  
Dry pastures or woods. Frequent.
- Leonurus cardiaca* L. Motherwort  
Infrequent along roadsides or around dwellings or floodplains of streams.
- Lycopus americanus* Muhl. Cut-leaved Bugleweed  
See Rhodora 38:374. 1936.  
Common in wet prairie meadow, pasture, borders of lakes and ponds.
- Lycopus asper* Greene Western Bugleweed  
Common in wet meadow of prairie and pasture.
- Lycopus uniflorus* Michx. Northern Bugleweed  
See Rhodora 38:374. 1936.  
On hummocks in a small swamp bordering an oxbow cutoff in Meadow Creek (10,010), Clay Co. Marshy ground around a woodland spring along the Des Moines River two and one-half miles west of Osgood (8,578), Palo Alto Co.
- Lycopus virginicus* L. Virginia Bugleweed  
See Rhodora 38:374. 1936.  
Wet meadow along Mud Lake (9,629), Clay Co. Five miles east of Ruthven in wet prairie (9,065), Palo Alto Co.
- Mentha arvensis* L. var. *canadensis* (L.) Briq. Hairy Wild Mint  
Wet meadow, southeast margin of Mud Lake (9,063); wet bank of Pickerel Run at Dickens (9,065); margin of ponds Dewey's Pasture (10,006), Clay Co.
- Mentha arvensis* L. var. *glabrata* (Benth.) Fernald Smooth Wild Mint  
Growing on a bed of dead *Carex lacustris* from which water had receded, Outlet of Lost Island Lake (8,570), Clay Co. North shore of the south bay of Virgin Lake (9,064); sandy floodplain along the Des Moines River one and one-half miles west of Osgood (10,005), Palo Alto Co.



- Monarda fistulosa* L. var. *mollis* (L.) Benth. Pale Horsemint  
*Monarda mollis* L.  
 Well drained slopes and terraces around ponds and Mud Lake in Dewey's Pasture (9,047) and (9,043), Clay Co. L.H. Pammel, (I.S.C. 97,781), Palo Alto Co. Frequent.
- Nepeta cataria* L. Catnip  
 Common in vacant lots, margin of woods and near dwellings. Introduced.
- Nepeta hederacea* (L.) Trevisan Ground Ivy  
 See *Rhodora* 23:289. 1921.  
 Near dwellings, escaped into woods. Frequent.
- Prunella vulgaris* L. var. *lanceolata* Fernald *Rhodora* 179-86. 1913. Self Heal  
 Low prairie, floodplain of streams and low woods.
- Physostegia speciosa* (Sweet) Sweet False Dragonhead  
 See *Flora of Indiana* p. 809. 1941.  
*Physostegia virginiana* in part of Gray Man. 7 ed. and *Dracocephalum virginianum* in part, of Britton and Brown, Illus. *Flora*, ed. 2.  
 Semi-open, willow shaded bank along the inlet of Round Lake (9,043); roadside ditch, two miles east of Spencer (9,045); on hummocks of a swamp near an oxbow cutoff in Meadow Creek northeast of Spencer (9,044 and 10,016) Clay Co.
- Pycnanthemum flexuosum* (Walt.) B.S.P. Narrow-leaved Mountain Mint  
 Wet prairie along the C.R.I. & St.P. railroad track five miles east of Ruthven near the viaduct in Highway 18 (11,408), Palo Alto Co.
- Pycnanthemum virginianum* (L.) Durand and Jackson Virginia Mountain Mint  
 Common in wet meadow, around ponds and sloughs.
- Salvia lancaefolia* Poir. Lance-leaved Sage  
 Dry hillsides in a pasture on the Adams Farm, five miles southwest of Gillett Grove (10,102), Clay Co. In a barnyard at the corner of Electric Park two miles north of Ruthven, Palo Alto Co. Introduced. Becoming common.
- Scutellaria epilibifolia* Hamilton Marsh Skullcap  
 See *Contr. U.S. Nat. Herb.* 28:723. 1927, and *Rhodora* 23:285. 1921.  
*Scutellaria galericulata* of Am. auth., not L. in *Am. Jour. Bot.* 26:17. 1939.  
 Frequent around ponds and Mud Lake in Dewey's Pasture (9,056 and 9,628); swampy margin of Mud Lake (9,082), Clay Co. Wet meadow of Hughes Prairie, two miles northeast of Lost Island Lake (9,084); wet meadow of south Mud Lake (9,086), Palo Alto Co.
- Scutellaria lateriflora* L. Mad Dog Skullcap  
 Swampy north margin of Mud Lake (9,054); wet meadow along the south side of Dan Green Slough (9,057), Clay Co.
- Scutellaria parvula* Michx. Small Skullcap  
 On the site of a haystack on bare ground in low prairie bordering the Outlet of Lost Island Lake (9,085), Clay Co. Five miles east of Ruthven growing in yellow clay around a rodent's den in upland prairie (9,087), Palo Alto Co.
- Stachys palustris* L. Hedge Nettle  
 Low prairie by roadside bridge west of Mud Lake (9,052); wet meadow, Outlet of Lost Island Lake (10,856), Clay Co. Low meadow southeast of Lost Island Lake (9,053), Palo Alto Co.
- Stachys tenuifolia* Willd. Smooth Hedge Nettle  
 Low, rich woods along the Little Sioux River, Wanata State Park, (10,004), Clay Co. Moist soil along the west border of Lost Island Lake (8,590), Palo Alto Co.
- Teucrium canadense* L. var. *virginicum* (L.) Eaton American Germander or Wood Sedge  
 See *Rhodora* 35:395. 1933.  
*T. canadense* of auth. not L.  
 North shore of Mud Lake (9,090), south margin of Round Lake (9,050), Clay Co.

Around the margin of a pond one-half mile south of the viaduct over Highway 18 five miles east of Ruthven (9,048), Palo Alto Co.

## SOLANACEAE (Nightshade Family)

*Physalis heterophylla* Nees Clammy Ground Cherry  
Sandy bank on the southeast side of Lost Island Lake. Abundant locally (2,055), Palo Alto Co.

*Physalis lanceolata* Michx. Prairie Ground Cherry  
Gravelly hilltop, Hughes prairie, two miles north of Lost Island Lake (2,057), Palo Alto Co.

*Physalis longifolia* Nutt. Long-leaved Ground Cherry  
Grassland, in the valley of the Little Sioux River, one mile east of Peterson (911); about two miles west of Ruthven along the north side of Highway 18 (9,540), Clay Co.

*Solanum nigrum* L. Black Nightshade  
Common along roadsides, in gardens and cultivated fields.

*Solanum carolinense* L. Horse Nettle  
Mallard, W.P. Reinders, (I.S.C. 103,142). Growing in a brush pile in Lost Island State Park (7,115), Palo Alto Co. Infrequent.

*Solanum rostratum* Dunal Buffalo Burr  
Occasional around barnyards or sandy floodplains of rivers. Introduced.

## SCROPHULARIACEAE (Figwort Family)

*Castilleja sessiliflora* Pursh Downy Paint Brush  
High, gravelly prairie hills, one mile east of Peterson (910 and 9,014), Clay Co. Prairie hill, about five miles east of Lost Island State Park (9,013), Palo Alto Co.

*Chelone glabra* L. Turtlehead  
Margin of a bog on the west branch of the Des Moines River below the bridge west of Osgood (9,682), Walnut Twp., Palo Alto Co.

*Gerardia aspera* Douglas Rough Gerardia  
See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. I. 1935.  
*Agalinus aspera* (Doug.) Brit.  
Vicinity of Gillett Grove, L.H. Pammel, (I.S.C. 53,471), Clay Co. Dry prairie hilltops five miles north of Lost Island Lake (7,524), Palo Alto Co.

*Gerardia paupercula* (Gray) Britton Small-flowered Gerardia  
See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. I. 1935.  
*G. purpurea paupercula* Gray.  
*Agalinus paupercula* (Gray) Britton.  
Recurrent in the wet meadow around hanging bogs and in wet prairie.

*Gerardia tenuifolia* Vahl. subsp. *parviflora* Nutt. Slender Gerardia  
See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. I. 1935.  
*Agalinus tenuifolia* Vahl. *parviflora* (Nutt.) Penn.  
*A. tenuifolia* Vahl. *macrophylla* (Benth.) Blake  
On hummocks in an oxbow cutoff in Meadow Creek, four miles northeast of Spencer (10,017), Clay Co. Sandy south shore of Lost Island (10,018), Palo Alto Co.

*Gratiola neglecta* Torr. Clammy Hedge Hyssop  
Wet, black soil in a bog along the west side of the Des Moines River, south of the bridge, one and one-half miles southwest of Osgood (9,035); pond two miles south of Lost Island State Park on the left side of the Road (9,020), Palo Alto Co.

*Linaria vulgaris* Hill. Butter and Eggs  
Occasional along roadsides, dwellings and in open woods. Introduced.

- Lindernia anagallidea* (Michx.) Penn. Short-stalked False Pimpernel  
 See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. 1:152. 1935.  
*Ilysanthes anagallidea* (Michx.) Raf.  
*I. inequalis* (Walt.) Pennell  
*Gratiola anagallidea* Michx.  
 Sandy beach of Lost Island Lake near the inlet below Electric Park (9,019), Palo Alto Co.
- Lindernia dubia* (L.) Pennell subsp. *typica* Pennell Long-stalked False Pimpernel  
 See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. 1:141. 1935.  
*Ilysanthes dubia* (L.) Barnh. in part  
 Around the muddy margin of a shallow pond one-fourth mile north of Lost Island Lake (11,443), Clay Co.
- Mimulus ringens* L. Square-stemmed Monkey Flower  
 Common around the borders of ponds and sloughs.
- Pedicularis canadensis* L. Wood Betony or Lousewort  
 Frequent on prairie slopes and on ridges in woods.
- Pedicularis lanceolata* Michx. Swamp Lousewort  
 Marsh along Pickerel Run at the entrance to Dickens (9,007), Clay Co. Along a swale in Hughes Prairie two miles northeast of Lost Island Lake (9,008); five miles east of Ruthven in the sedge zone of a hanging bog (10,014), Palo Alto Co.
- Scrophularia lanceolata* Pursh Lance-leaved Figwort  
 See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. 1:275. 1935.  
*S. leporella* Bicknell  
*S. nodosa* L. *occidentalis* Rydb.  
 West Bend, R. I. Cratty, (I.S.C. 96,369), Palo Alto Co.
- Scrophularia marilandica* L. Maryland Figwort  
 Gillett Grove, L.H. Pammel, (I.S.C. 78,369), Clay Co. Open woodland along the Des Moines River (9,036), Palo Alto Co.
- Tomanthera auriculata* (Michx.) Rafinesque  
 See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. I. 1935.  
*Gerardia auriculata* Michx.  
 Growing in moist soil of a shallow drainageway running through level ground in a fallow oatfield on the Fitzgerald Farm six miles north of Ruthven (7,526), Clay Co.
- Verbascum thapsus* L. Great Mullein  
 Common along the margin of woods. Floodplains of stream and in overgrazed pastures.
- Veronica connata* Raf. Water Speedwell  
 See Acad. Nat. Sci. Phila. Scrophulariaceae of E. Tem. N.A. Mon. I. 1935.  
*V. anagallis-aquatica* of auth. in part. not L.  
 Springy bank of Pickerel Run near the entrance to Dickens (10,019), Clay Co.  
 Growing in running water in the inlet of Lost Island Lake (9,017); in a spring emerging from a hanging bog along the Des Moines River (9,018), Palo Alto Co.
- Veronica peregrina* L. Neckweed  
 Cultivated fields, roadsides and neglected ground. Frequent. Introduced.
- Veronicastrum virginicum* (L.) Farwell, Drug Cir. 61:231. 1917. Culver's Root  
*Veronica virginica* L.  
*Leptandra virginica* (L.) Nutt.  
 Frequent in low prairie.

#### LENTIBULARIACEAE (Bladderwort Family)

- Utricularia intermedia* Hayne Flat-leaved Bladderwort  
 Outlet of Lost Island Lake about four miles northwest of Ruthven. Shallow,

grassy margin of marsh in clear water (10,054 and 10,055), Clay Co. Uncommon.

*Utricularia vulgaris* L. var. *americana* Gray

Greater Bladderwort

Abundant in sloughs and marshy lakes such as Round, Mud, Dan Green Slough and Johnson's Slough.

#### PLANTAGINACEAE (Plantain Family)

*Plantago lanceolata* L.

Lance-leaved Plantain

Occasional, in clover and timothy fields, roadsides and farmyards.

*Plantago major* L.

Greater Plantain

Common in hard paths, dooryards, roadsides and fields.

*Plantago purshii* R. & S.

Pursh's Plantain

Common on gravelly plain along the Des Moines River (10,059), Palo Alto Co.

*Plantago rugelii* Dcne.

Rugel's Plantain

A pioneer of neglected soil.

#### PHRYMACEAE (Lopseed Family)

*Phryma leptostachya* L.

Lopseed

Frequent, in woods.

#### RUBIACEAE (Madder Family)

*Galium aparine* L.

Cleavers

Common in low woods. Introduced.

*Galium boreale* L.

Northern Bedstraw

Pammel, Fisk and Saunders, (I.S.C. 126,201), Palo Alto Co.

*Galium boreale* L. var. *hyssopifolium* (Hoffm.) DC. Hyssop-leaved Northern Bedstraw

See Rhodora 30:106-07. 1928.

Two miles west of Ruthven on the south side of the Outlet of Lost Island Lake in low prairie (9,644), Clay Co.

*Galium boreale* (L.) var. *intermedium* DC.

Northern Bedstraw

One mile east of Lost Island State Park in roadside, prairie (10,024), Palo Alto Co.

*Galium concinnum* Torr. and Gray

Shining Bedstraw

In rich woods along the Little Sioux River at Gillett Grove (2,021), Clay Co.

*Galium obtusum* Bigel.

Blunt-leaved Bedstraw

See Rhodora 37:443-45. 1935.

*G. tinctorium* L.

West side of Dewey's Pasture in wet soil around ponds. Low prairie (2,019), Clay Co.

*Galium triflorum* Michx. forma *hispidum* Leyendecker Three-flowered Bedstraw

Shady slopes bordering a tributary of the Little Sioux River at Peterson (938 and 2,020), Clay Co.

#### CAPRIFOLIACEAE (Honey Suckle Family)

*Sambucus canadensis* L.

Elderberry

Open woodland along lakes and in fencerows.

*Lonicera prolifera* (Kirsh.) Rehder

Twining Honeysuckle

See Rhodora 12:166. 1910.

*L. sullivanii* Gray

Frequent on wooded hills of the Little Sioux River at Gillett Grove (925, 2,053, and 10,244), Clay Co.

*Symphoricarpos occidentalis* Hook.

Western Buckbrush

Common in open woods, pastures and along roadsides.

*Triosteum perfoliatum* L.

Horse Gentian

Infrequent in dry woods.

*Viburnum rafinesquianum* Schult. var. *affine* (Schneid.) House

Downy-leaved Arrow-wood

See *Rhodora* 20:14. 1918.

*Viburnum affine* Bush

*V. pubescens* of auth., not Pursh

Cut over woodland slopes along Highway 10 at the west entrance to Peterson (2,044), Clay Co.

*Viburnum lentago* L.

Nannyberry

A member of the pioneer association of cut-over timber on the west side of Peterson (2,043); along a stream in Adams Woods three miles west of Gillett Grove (2,042 and 10,379), Clay Co. Along the north rocky bank of Silver Lake (2,041), Palo Alto Co.

#### CUCURBITACEAE (Gourd Family)

*Echinocystis lobata* (Michx.) T. & G.

Wild Balsam Apple

Climbing over bushes on the north bank of Mud Lake (2,035), Clay Co. South of Graettinger along the floodplain of the Des Moines River (5,004), Palo Alto Co. Frequent on lake banks and along rivers.

#### CAMPANULACEAE (Bluebell Family)

*Campanula americana* L.

American Bellflower

Frequent but sparsely distributed in moist shaded woods.

*Campanula aparinoides* Pursh

Bedstraw Bellflower

In wet meadow around the edge of the marshy outlet of Lost Island Lake (9,559 and 9,098), Clay Co. Sedge zone around a hillside spring on the west side of the Des Moines River two miles west of Osgood 7,438), Palo Alto Co.

*Campanula rapunculoides* L.

European Bellflower

Roadside banks. Escaped from cultivation.

*Campanula uliginosa* Rydb.

Blue Marsh Bellflower

Wet meadow on the Oliver Farm southwest of Lost Island Lake (2,037), Clay Co. West Bend, R.I. Cratty (I.S.C. 96,038), Palo Alto Co.

*Specularia perfoliata* (L.) A. DC.

Venus Looking-glass

Infrequent in open woods or pastures.

#### LOBELIACEAE (Lobelia Family)

*Lobelia kalmii* L.

Kalm's Lobelia

Hanging bog along the Little Sioux River (9,071), Clay Co. Wet meadow in hanging bog five miles east of Ruthven, south of viaduct in Highway 18 (2,030), Palo Alto Co.

*Lobelia spicata* Lamarck var. *hirtella* Gray

Pale Spiked Lobelia

See *Rhodora* 38:313. 1936.

On knolls in Dewey's Pasture (2,031), Clay Co. Low meadow southwest of Lost Island Lake (2,033), Palo Alto Co. Frequent in moist prairie.

*Lobelia siphilitica* L.

Great Lobelia

See *Rhodora* 38: 278. 1936.

Frequent in wet prairie or in open woods.

*Lobelia siphilitica* (L.) var. *hudsoniana* A. DC.

Western Great Lobelia

See *Rhodora* 38:281. 1935.

Wet meadow bordering sloughs and swamps.

#### COMPOSITAE (Sunflower Family)

*Achillea lanulosa* Nutt.

Woolly Yarrow

Roadsides, prairie and overgrazed pastures.

- Achillea millefolium* L. Green Yarrow  
Roadsides, prairie and pastures.
- Agoseris cuspidata* (Pursh) Steud. Prairie False Dandelion  
Gravelly hilltops and slopes.
- Ambrosia artemisiaefolia* L. var. *elator* (L.) Desc. Lesser Ragweed  
See Rhodora 37:185. 1935.  
*Ambrosia artemisiifolia* of auth., not L.  
Common in cultivated land and overgrazed pastures.
- Ambrosia artemisiaefolia* L. f. *villosa* Fernald and Griscom Villous Lesser Ragweed  
Rhodora 37:185. 1935.  
Zone around a pond in Dewey's Pasture eight miles north of Ruthven (10,707);  
on a hummock in a wet meadow around an oxbow cutoff in Meadow Creek about  
four miles northeast of Spencer (10,894), Clay Co.
- Ambrosia coronopifolia* T. & G. Western Ragweed  
*Ambrosia psilostachya* DC.  
Dry slopes of knolls in Dewey's Pasture seven miles north of Ruthven (10,708),  
Clay Co. North sandy bank of Silver Lake (10,710), Palo Alto Co.
- Ambrosia longistylis* Nutt. Long-styled Ragweed  
At the edge of a dry pasture at the entrance to the bridge over the west fork of  
the Des Moines River west of Osgood (10,709), Palo Alto Co.
- Ambrosia trifida* L. Greater Ragweed or Horsecweed  
*Ambrosia striata* Rydb.  
Alluvial ground, fields and waste ground.
- Antennaria neglecta* Greene Field Cat-foot  
Two miles west of Graettinger on the gravelly terrace of the Des Moines River  
(11,300), Palo Alto Co.
- Antennaria plantaginifolia* L. Plantain-leaved Everlasting  
Open woods and hills along the Little Sioux River in Wanata State Park (10,045),  
Clay Co.
- Anthemis cotula* L. Mayweed or Dog Fennel  
Common in barnyards, pastures and along roadsides.
- Arctium minus* Bernh. Common Burdock  
Common in waste ground and around dwellings.
- Artemisia biennis* Willd. Biennial Wormwood  
Wet soil around a pond in a semi-dried marsh (10,719), Clay Co. Along the  
south shore of Lost Island Lake, Palo Alto Co.
- Artemisia campestris* L. var. *caudata* (Michx.) Palmer and Steyermark  
Linear-leaved Wormwood or Sage  
*A. caudata* Michx.  
*A. campestris* subsp. *caudata* (Michx.) Hall and Clements  
Sandy beach on the east side of Lost Island Lake (10,716), Palo Alto Co.
- Artemisia dracuncululus* L. var. *glauca* Jepson Tall Wormwood or Sage  
*A. dracunuloides* Pursh.  
Dry gravelly beach one-half mile south and one mile east of Lost Island Lake  
(10,717), Palo Alto Co.
- Artemisia serrata* Nutt. Serrate Wormwood or Sage  
Prairies, and sandy lake banks; Dewey's pasture, Clay Co. Northeast sandy  
bank of Lost Island Lake, Palo Alto Co.



*Artemisia vulgaris* L. var. *gnaphalodes* (Nutt.) Kuntze      Prairie Wormwood or Sage  
Roadside two miles north of Spencer (10,712); dry hills along the Little Sioux  
River, two miles south of Gillett Grove (10,711), Clay Co.

*Artemisia vulgaris* L. var. *ludoviciana* (Nutt.) Ktze.      Dark-leaved Wormwood or Sage  
Sandy beach on the north side of Silver Lake (10,720), Palo Alto Co.

× *Aster amethystinus* Nutt.      Amethyst Aster  
Rhodora 32:1-3. 1930.  
Rhodora 41:190-92. 1939.  
Amer. Jour. Bot. 26:1-12.  
*A. ericoides* × *A. novae-angliae*

About seven miles north of Ruthven in Dewey's Pasture growing on moist hum-  
mocks on the west side of the swale west of the hill above Mud Lake (11,134, 11,136, and  
11,137); Dewey's Pasture about 500 feet west of the first colony near a pond (11,133),  
Clay Co. These colonies were located in 1936, but disappeared in 1938. They grow  
in moist (not wet) soil, so the fluctuation of water level may have a bearing on their  
occurrence. A colony was located in 1938 in moist soil on the west side of the west  
lagoon slough of Virgin Lake (11,135), Palo Alto Co.

*Aster angustus* (Lindl.) T. & G.      Rayless Aster  
*Brachyactis angusta* (Lindl.) Brit.

Along the sandy southeast shore of Round Lake near the large cottonwood trees  
(11,074); around the sandy northwest bank of Mud Lake in Dewey's Pasture in  
alkaline soil (11,073), Clay Co. Along the marshy north border of the west lagoon  
of Virgin Lake (11,075), Palo Alto Co.

*Aster cordifolius* L.      Heart-leaved Aster  
Moist wooded hillsides along the Little Sioux River (11,098), Clay Co. Abundant  
locally.

*Aster commutatus* (T. & G.) A. Gray      White Prairie Aster  
See Syn. Fl. 1:185. 1884.  
*A. multiflorus* var. *commutatus* T. & G.  
*A. incanopilosus* Sheld.  
South shore of Lost Island Lake on a dry prairie hillside on the Loesser (Babcock)  
Farm (11,154), Palo Alto Co.

*Aster ericoides* L.      Many-flowered Aster  
See Rhodora 32:138. 1930, and 30:227. 1928.  
*A. multiflorus* Ait.  
*A. multiflorus* Ait. var. *exiguus* Fernald  
High prairie two miles east of Peterson (11,119); knolls in Dewey's Pasture (11,107,  
11,108, 11,110, 11,111, and 11,123), Clay Co. Five miles east of Ruthven prairie along  
the railroad track (11,112); two miles north of Lost Island Lake in Hughes Prairie  
(11,125); roadside bank two miles east of Ruthven (11,127), Palo Alto Co. Frequent.

*Aster ericoides* L. forma *caeruleus* (Benke) Blake      Blue Many-flowered Aster  
See Rhodora 30:227. 1928, 32:138. 1930.  
*A. columbianus* Piper  
*A. multiflorus* var. *caeruleus* Benke  
*A. multiflorus* var. *columbianus* Blake  
Dewey's Pasture along the south trail (11,129 and 11,132), Clay Co. Two miles  
south of Ruthven on a bank west of Virgin Lake School (11,114, 11,116, 11,130, 11,141);  
prairie slope above the fringe of woods around Lost Island Lake on the Loesser (Bab-  
cock) Farm (11,115), Palo Alto Co.

*Aster ericoides* L. var. *prostratus* (Ktze.) Blake      Spreading-haired Many Flowered Aster  
See Rhodora 32:138. 1930.  
*A. exiguus* (Fernald) Rydb.  
*A. multiflorus* Ait. var. *pansus* Blake, in Rhodora 30:227. 1928.  
Dewey's Pasture in blue grass on knolls (11,109), Clay Co. Prairie south of Ruth-  
ven near Silver Lake (11,120), Palo Alto Co.

*Aster junceus* Ait.

Rush Aster

Swampy land northeast of Lost Island Lake (11,166), sedge zone of a fen five miles east of Ruthven (7,527), Palo Alto Co. Similar habitat along Elk Creek (7,528) in Sec. 16, Logan Twp., Clay Co.

*Aster laevis* L.

Smooth Aster

On the northwest side of Lost Island Lake, where the road leaves the highway (11,058) and (11,088), Clay Co. Along the roadside, north of Lost Island Lake (11,089); five miles south of Ruthven on the road to Silver Lake (11,090), Palo Alto Co. Frequent.

*Aster novae-angliae* L.

New England Aster

Moist roadside north of Lost Island Lake occurring in a tall purple hedge just in front of a taller zone of the clear blue *Aster puniceus* (11,066), Clay Co. Prairie five miles south of Ruthven on the road to Silver Lake (11,067), Palo Alto Co. Frequent in pastures, (especially Dewey's), and along roadsides.

*Aster oblongifolius* Nutt.

Oblong-leaved Aster

Roadside bank north of Lost Island Lake (11,076); grassy knoll, Dewey's Pasture near Mud Lake (11,155); high gravelly prairie hilltop one mile east of Peterson (11,118), Clay Co.

*Aster oblongifolius* Nutt. var. *rigidulus* Gray

Rigid Oblong-leaved Aster

Open hilltop at the edge of woods, in shade part of the day, Babcock Farm south shore of Lost Island Lake (11,077); roadside bank north of the Lake School and south of Lost Island Lake (11,080), Palo Alto Co.

*Aster paniculatus* Lam. var. *simplex* (Willd.) Burgess

Panicked Aster

See *Rhodora* 35:32. 1933.

*A. salicifolius* Ait. in part

Abundant and widespread. Occurring in a moist zone slightly elevated above ponds. Common along roadsides. Conspicuous in Dewey's Pasture, Clay Co.

*Aster pantotrichus* Blake

Panicked Lateral-flowered Aster

Jour. Wash. Acad. Sci. 21: 327. 1936.

*A. missouriensis* Britton not Ktze.

*A. lateriflorus* (L.) Britton var. *thyrsoides* (Gray) Sheldon.

Abundant along the floodplain of the Little Sioux River at Peterson (11,149, 11,150, 11,151, and 11,153), Clay Co. Under willows at right angles to Highway 341 and east of the M. & St.L. railway at the north edge of Ruthven (11,157), Palo Alto Co.

*Aster praealtus* Poir.

Willow-leaved Aster

See *Rhodora* 35:21. 1933.

*A. salicifolius* in part.

Dewey's Pasture, moist soil along water (11,177), Clay Co.

*Aster ptarmicoides* T. & G.

Upland White Aster

High prairie three miles south of Ruthven and west of Virgin Lake (9,560) and 10,593), Palo Alto Co.

*Aster puniceus* L.

Red-stalked Aster

Frequent in wet prairie along the border of sloughs and marshes and around hanging bogs.

*Aster sagittifolius* Wedemeyer

Arrow-leaved Aster

Wooded hillsides above the Little Sioux River in Wanata State Park at Peterson (11,101 and 11,102), Clay Co. Abundant locally.

*Aster sericeus* Vent.

Silky-leaved Aster

High prairie, two miles east of Peterson (11,069); one mile east of Gillett Grove on high prairie covered hills (11,070), Clay Co. High prairie south of Virgin Lake (11,068), Palo Alto Co.

*Aster umbellatus* Mill.

Flat-topped Cream-flowered Aster

Abundant in the *Carex* zone of hanging bogs, also wet prairies.

- Bidens cernua* L. Nodding Bur Marigold  
Common around the low shores of lakes, borders of ponds and streams.
- Bidens cernua* L. var. *oligodonta* Sherff  
Pub. 388. Field Mus. Nat. Hist. 16:301. 1937.  
Sandy north beach of Lost Island Lake (10,866), marshy border of stream, Hughes Prairie (11,867), Palo Alto Co.
- Bidens comosa* (Gray) Wiegand Leafy-bracted Tickseed  
Ponds and border of Mud Lake (10,864 and 10,920), Clay Co.
- Bidens frondosa* L. Beggar Ticks or Sticktight  
See Pub. 388. Field Mus. Nat. Hist. 16:236. 1937.  
Margin of ponds in dried ponds Dewey's Pasture (10,872); low shady woods along the Little Sioux River, Wanata State Park (10,874) Clay Co. Marshy north shore of Virgin Lake (10,877), Palo Alto Co.
- Bidens vulgata* Greene Tall Beggar Ticks  
North shore of Lost Island Lake (10,876), Clay Co.
- Boltonia latisquama* Gray var. *microcephala* Fernald and Griscom Broad-scaled Boltonia  
See Rhodora 42:484.  
Commonly referred to *B. asteroides* (L.) L' Her. which occurs in eastern United States. Frequent around the borders of sloughs and ponds and lakes.
- Calacia tuberosa* Nutt. Indian Plantain  
Frequent in moist level prairie, sometimes occurring in upland in rich soil.
- Cichorium intybus* L. Chicory  
Two miles east of Emmetsburg roadside (10,799), Palo Alto Co.
- Cirsium altissimum* (L.) Spreng. Tall or Iowa Thistle  
See Beih. z. Bot. Centralbl. II 35:396-400. 1917.  
*C. iowense* (Pammel) Fernald  
Common along roadsides and in fields.
- Cirsium arvense* (L.) Scop. Canada Thistle  
Common in cultivated fields, pastures and roadsides.
- Cirsium discolor* (Muhl.) Spreng. Field Thistle  
Roadsides and open woods. Frequent.
- Cirsium flodmanii* (Rydb.) Arthur Woolly Thistle  
*C. canescens* A. Gray, not Nutt.  
Frequent in prairie, pastures and along roadsides.
- Cirsium lanceolatum* (L.) Hill Bull Thistle  
Common in pastures.
- Coreopsis palmata* Nutt. Prairie Coreopsis or Stiff Tickseed  
Common in upland prairie.
- Coreopsis tinctoria* Nutt. Garden Coreopsis  
Abundant locally in an alfalfa field at the northwest edge of Ruthven (10,760), Palo Alto Co. Roadside in Spencer, Clay Co.
- Dyssodia papposa* (Vent.) Hitchc. Fetid Marigold  
In a barnyard along Highway 10 about two miles east of Peterson (10,701), Clay Co.
- Echinacea angustifolia* DC. Narrow-leaved Purple Cone-flower  
*Brauneria angustifolia* (DC.) Heller  
Native prairie, one mile east of Peterson (906); Dewey's Pasture, on knolls in blue grass (10,692), Clay Co. High prairie roadside one mile east of Lost Island Lake (10,689), Palo Alto Co.

- Erigeron annuus* (L.) Pers. White-top  
Common in hay fields, pastures, roadsides and open woods.
- Erigeron canadensis* L. Horse Weed or Canada Fleabane  
Common in dry or overgrazed pastures. Was abundant in Dewey's Pasture when it was grazed. Becoming less frequent.
- Erigeron philadelphicus* L. Philadelphia Fleabane  
Moist slopes of hills and wet shores of lakes. Frequent.
- Erigeron strigosus* Muhl. Daisy Fleabane  
See Rhodora 44:340. 1942.  
*Erigeron ramosus* (Walt.) BSP. of manuals  
Frequent in pastures, open woods and along roadsides.
- Eupatorium perfoliatum* L. Boneset  
Frequent in marshy ground including hanging bogs.
- Eupatorium fistulosum* Barratt Joe Pye Weed  
See Rhodora 39:306. 1937.  
*E. purpureum sensu* Mack. in Rhodora 22:161. 1920 not L.  
Frequent around the wet borders of marshes, lakes or in the *Carex* zone of hanging bogs.
- Eupatorium rugosum* Houtt. White Snakeroot  
See Rhodora 40:293. 1938.  
*E. urticaefolium* Reichard  
Frequent in woods along the base of hills and on shaded roadsides, lake banks.
- Grindelia squarrosa* (Pursh) Dunal Tarweed  
Infrequent in pastures and around ponds, and along roadsides.
- Helenium autumnale* L. Sneezeweed  
Wet meadow around marshes and bogs.
- Helianthus annuus* L. Annual Sunflower  
Cornfields and roadsides. Infrequent.
- Helianthus divaricatus* L. Divaricate Sunflower  
Openings in woodland slopes, Wanata State Park, Peterson (10,142), Clay Co.
- Helianthus grosseserratus* Martens Serrate-leaved Sunflower  
Abundant along roadsides, in cultivated fields, roadsides and occasional in prairie.
- Helianthus laetiflorus* Pers. Showy Sunflower  
Prairie slope along roadside about one mile east of Peterson (10,741); open roadside west of Mud Lake (10,748); roadside banks one-half mile north of Graettinger (10,744), Palo Alto Co.
- Helianthus maximiliani* Schrad. Maximilian's Sunflower  
Prairie knolls in Dewey's Pasture (10,729); roadside bank four miles east of Ruthven between Mud and Lost Island Lakes (10,730); open roadside west of Mud Lake (10,749), Clay Co. Two miles east of Ruthven in prairie along the roadside near the Lake School (10,726), Palo Alto Co. Frequent.
- Helianthus rigidus* (Cass.) Desf. Stiff Sunflower  
See Papers Mich. Acad. Sci. 9:344. 1929.  
*H. scaberrimus* Ell.  
Frequent along roadsides and in dry prairie.
- Helianthus tuberosus* L. Artichoke  
Common in open woods, prairie, roadsides and in cultivated fields.

- Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dunal) Fernald Ox-eye  
 Rhodora 44:340. 1942.  
*Heliopsis scabra* Dunal.  
 East of Trumbull Lake (9,666), Clay Co. North of Lost Island Lake along a  
 roadside bank (10,750), Palo Alto Co. Infrequent.
- Iva xanthifolia* Willd. Marsh Elder  
 Occasional in pastures, barnyards and roadsides.
- Kuhnia eupatorioides* L. False Boneset  
 Prairie, pastures and roadsides. Frequent.
- Lactuca campestris* Greene Western Wild Lettuce  
 Frequent along roadsides and in prairie. Rays pinkish purple. Sometimes mis-  
 taken for *L. ludoviciana*, which has yellow rays.
- Lactuca floridana* (L.) Gaertn. Florida Wild Lettuce  
 Open woodland, Wanata State Park, one mile south of Peterson (9,897), Clay Co.
- Lactuca pulchella* (Pursh) DC. Blue Wild Lettuce  
 Roadside along Highway 18, one-half mile west of Ruthven (10,595), Clay Co.
- Lactuca scariola* L. Prickly Lettuce  
 Common in waste ground.
- Lactuca scariola* L. var. *integrata* Gren. and Godr. Prickly Wild Lettuce  
*L. virosa* of Am. auth., not L.  
 Frequent along roadsides and in waste ground.
- Lactuca canadensis* L. Canada Lettuce  
 Frequent on roadsides or prairies.
- Liatris acidota* Engelm. and Gray Dotted Blazing Star  
*L. punctata* of auth. not Hook.  
*Lacinaria angustifolia* Bush.  
 Gravelly prairie in cemetery at Dickens (10,528); gravelly hilltops in Dewey's  
 Pasture, Clay Co. Along prairie roadside two miles east of Ruthven (10,529); gravelly  
 knoll on the Hughes Farm, common locally (10,530), Palo Alto Co.
- Liatris pycnostachya* Michx. Hairy Blazing Star  
*Lacinaria pycnostachya* (Michx.) Kuntze  
 Common in low prairie.
- Liatris scariosa* Willd. Upland Button Snakeroot or Blazing Star  
 High prairie hilltop one mile east of Peterson (10,541), Clay Co. Five miles east  
 of Ruthven south of viaduct over Highway 18. Infrequent on upland prairie slopes.
- Liatris squarrosa* (L.) Hill Scaly or Squarrose Blazing Star  
 Prairie hilltop southwest of Virgin Lake. Common locally (10,532), Palo Alto  
 Co. Infrequent in region.
- Lygodesmia juncea* (Pursh) G. Don Bundle-of-switches  
 Two miles east of Ruthven in sandy soil by the roadside; also in nearby fields  
 (10,526), Palo Alto Co.
- Matricaria matricarioides* (Less.) Porter Rayless Camomile  
 Along the M. & St. P. railroad station at Ruthven (10,596); edge of sidewalk on  
 the main street of Ruthven (10,700), Palo Alto Co.
- Prenanthes aspera* Michx. Rough White Lettuce  
*Nabalus asper* (Michx.) T. & G.  
 Dry upland prairie. Frequent in wet seasons.
- Prenanthes racemosa* Michx. Glaucous White Lettuce  
*Nabalus racemosus* (Michx.) DC.  
 Moist prairie. Most common in wet seasons.

- Ratibida columnaris* (Sims) D. Don Long-headed yellow cone-flower  
*Lepachys columnaris* (Sims) T. & G.  
 In bluegrass along roadside, in a lane which leads to Trumbull Lake west of Dewey's Pasture. Rare. Clay Co.
- Ratibida pinnata* (Vent.) Barnhart Gray-headed Cone-flower  
 Frequent in pastures, along roadsides and in prairie.
- Rudbeckia hirta* L. Black-eyed Susan  
*R. sericea* Moore  
*R. longipes* Moore  
 Frequent in moist prairie.
- Rudbeckia laciniata* L. Compass Plant  
 Frequent in upland prairie.
- Rudbeckia triloba* L. Thin-leaved Cone Flower  
 Infrequent in low woods.
- Senecio aureus* L. Golden Ragwort  
 Low prairie, around the swampy Outlet of Lost Island Lake (10,611), Clay Co.  
 Low prairie about three miles east of Lost Island Lake (9,790); about eight miles east of Emmetsburg (10,612), Palo Alto Co.
- Senecio integerrimus* Nutt. Entire-leaved Groundsel  
 Open grassland at the southeast edge of Graettinger (10,564); low prairie along Highway 17, about one mile north of Graettinger (10,565); on the south shore of Lost Island Lake in the border of woods on the Loesser (Babcock) Farm (9,791), Palo Alto Co.
- Senecio pauperculus* Michx. Balsam Groundsel  
 Rocky prairie hillside three miles west of Gillett Grove on the Adams Farm (10,380 and 10,563), Clay Co.
- Silphium laciniatum* L. Compass Plant or Rosin Weed  
 Frequent in prairie.
- Silphium perfoliatum* L. Cup Plant  
 Frequent in low ground near woods, or in moist prairie.
- Solidago altissima* L. Tall Goldenrod  
 This is commonest species in this region, occurring in prairies, fields, and thickets. Blooming period July 20-August 20 distinguishes it from *S. canadensis* L. var. *gilvocanescens* Rydb., which blooms a month later.
- Solidago canadensis* L. var. *gilvocanescens* Rydb. Crescent Canada Goldenrod  
*S. gilvocanescens* (Rydb.) Smyth  
 Fields and prairies. Abundant in Dewey's Pasture where it occurs in a zone between the ponds or the lake border and a zone occupied by *S. altissima*. Both species flourished when this area was pastured, but since the blue grass has grown tall and thick, *S. canadensis* var. *gilvocanescens* in the summer of 1939 showed a marked decrease in stand.
- Solidago glaberrima* Martens Smooth Prairie Goldenrod  
*S. missouriensis* of auth., not Nutt.  
 Frequent on upland prairie.
- Solidago glaberrima* Martens var. *moritura* (Steele) Palmer and Steyermark Narrow-leaved Smooth Goldenrod  
*S. glaberrima* Steele  
 Frequent in the same location with the species.
- Solidago graminifolia* (L.) Salisb. Flat-topped Goldenrod  
*Euthamia glutinosa* Rydb.  
 Wet soil along the marshy border of Pickerel Run at the east entrance to Dickens (16,645), Clay Co. Wet soil around the margin of a hanging bog, five miles east of Ruthven, south of the viaduct over Highway 18 (10,643), Palo Alto Co.



- Solidago gymnospermoides* (Greene) Fernald Viscid Bushy Goldenrod  
*Euthamia gymnospermoides* Greene  
 Sandy roadside and pasture nine miles east of Ruthven (10,644); three miles east of Lost Island Lake and one mile north of the Highway 18, gravelly bank by roadside (10,685), Palo Alto Co.
- Solidago latifolia* L. Broad-leaved Goldenrod  
 Wooded slopes along the Little Sioux River two and one-half miles east of Spencer (10,019); shaded slopes along the Little Sioux River in Wanata State Park (10,620), Clay Co. Slopes of hills, shaded, along the West Fork of the Des Moines River north of Graettinger (10,018), Palo Alto Co.
- Solidago nemoralis* Ait. Gray Goldenrod  
 High prairie southwest of Virgin Lake (10,661); dry roadside two miles east of Ruthven (10,666); dry gravelly hilltops south of Lost Island Lake (10,655), Palo Alto Co.
- Solidago nemoralis* Ait. var. *decemflora* (DC.) Fernald Long-petioled Gray Goldenrod  
 Rhodora 38:226. 1936.  
*S. pulcherrima* Nelson  
*S. longipetiolata* Mack. and Bush.  
 Gravelly prairie southwest of Lost Island Lake (11,208), Clay Co.
- Solidago riddellii* Frank Riddell's Goldenrod  
 Moist prairie along Pickerel Run at the east entrance to Dickens (10,627), Clay Co. In a meadow of sedge around a hanging bog five miles east of Ruthven (10,624 and 10,625), Palo Alto Co.
- Solidago rigida* L. Stiff Goldenrod  
 Frequent in prairie, pastures and roadsides.
- Solidago speciosa* Nutt. var. *angustata* T. & G. Narrow-leaved Showy Goldenrod  
*S. rigidiuscula* (T. & G.) Porter  
 Prairie two miles west of Ruthven (10,640), Clay Co. High prairie southwest of Virgin Lake (10,638); upland prairie one mile south of the viaduct over Highway 18 (10,641), Palo Alto Co.
- Solidago gigantea* Ait. var. *leiophylla* Fernald, Rhodora 41:457. 1939  
*S. serotina* Ait. Serrate-leaved Goldenrod  
 Depression along roadside near the bridge over Lost Island Lake (10,664), Clay Co. Moist depression at roadside one mile east of Ruthven on the Lake School road, Palo Alto Co. Frequent.
- Sonchus arvensis* L. var. *glabrescens* Guenth. Smooth Perennial Sow Thistle  
 Grab, and Wimm. Enum. Stirp. Phan. Siles p. 27, 1824.  
 See Torrey 22:92. 1922.  
*S. uliginosus* Bieberstein Flora Taurico-Caucasica 2:238. 1808.  
 About 10 miles south of Spencer, a small patch on the grassy shoulder of Highway 71 (10,815); three miles east of Spencer on the grassy shoulder of Highway 18 (10,821); two miles west of Ruthven along the grassy highway, not observed before 1938 (10,821); growing by a culvert at a fence corner about five miles west of Ruthven on the highway where it has grown vigorously from 1934-38 and has never been cut, Clay Co. Along roadside in a sod of *Agropyron repens*, a few rods east of the C.M.St.P. Railroad track on the north side of the highway, a patch 12-15 ft. long has been cut, dug and smothered but still persists (10,816); two small patches have been growing between pile of ties in front of the Spahn and Rose Lumber Yard for five years (10,818); scattered plants occur along the shore of Lost Island Lake west of the highway bridge (10,819). Scattered through a patch of Soy Beans one mile east of Ruthven (7,574), Palo Alto Co.
- Sonchus asper* (L.) Hill Spiny-leaved Sow Thistle  
 Not infrequent in waste ground.
- Sonchus oleraceus* L. Cabbage-leaved Sow Thistle  
 Back of stores on the main street of Ruthven (10,853), Palo Alto Co.

- Tanacetum vulgare* L. Tansy  
Six miles northwest of Emmetsburg along Highway 17 (10,601), Palo Alto Co.
- Taraxacum laevigatum* (Willd.) DC. Red-seeded Dandelion  
See Rhodora 35:379. 1933.  
*T. erythrospermum* Andrz.  
*Leontodon erythrospermum* (Andrz.) Brit.  
Gravelly prairie along the railroad tracks, one mile north of Graettinger (10,592), Palo Alto Co.
- Taraxacum palustre* (Lyons) Lam. & DC. var. *vulgare* (Lam.) Fernald White-seeded Dandelion  
Rhodora 35:380. 1933  
*Taraxacum officinale* Weber  
*Leontodon taraxacum* L.  
Common in lawns, pastures and roadsides.
- Tragopogon pratensis* L. Goat's Beard or False Salsify  
Roadsides, hayfields, pastures and railroads (10,603), Palo Alto Co.
- Verbesina enceloides* (Cav.) B. & H. var. *exauriculata* Robinson and Greenman Golden Crownbeard  
In the margin of a millet field two miles east of Ruthven, east of the Lake School (10,550), Palo Alto Co.
- Vernonia fasciculata* Michx. Fascicled Iron Weed  
Frequent in low ground.
- Xanthium italicum* Mor. Common Cockle Burr  
*X. glanduliferum* Greene  
*X. commune* Brit.  
Frequent in cultivated fields, around the margin of ponds and filling the bed of dried ponds.



## BREEDING RECORDS OF RATS FED CERTAIN DIETS CONTAINING MEAT<sup>1</sup>

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In preliminary studies reported in 1931, Nelson and her co-workers noted the nutritional ineffectiveness of certain meat diets when fed to the albino rat. Later (1935), Nelson, Hoyt, McLaughlin, and Morgan, in a survey of the food consumption habits of 145 Iowa farm families, found that the average consumption per adult male unit per year for the group was 173 lb. In certain families, as much as 500 lb. per man per year was consumed. Since meat occupied so prominent a place in the list of food commodities commonly consumed by many of the people of Iowa, it seemed important to reinvestigate by means of the biological feeding experiment, the rôle meat may play in nutrition when it serves as the chief protein constituent in an experimental ration deemed adequate in all the essential nutrients.

A bioassay of this kind presents certain difficulties and problems in the choice of criteria for the evaluation of the efficiency of the protein in the ration. A study of the long train of biochemical investigations initiated by the classic experiments (1911) of Osborne and Mendel dealing with the nutritive value of proteins derived from different food sources, shows that many indexes have been used in attempts to measure the nutritive value of the specific protein employed. Rate of induced growth, nitrogenous metabolism, and success in bearing and rearing of young have been appraised most frequently. The use of any one of the indexes has varied in the hands of different investigators. Growth, for example, has often been studied in relatively short portions of the normal life span and in periods of life when only gross dietary deficiencies may manifest themselves. Interpretation of rate of growth has been another variable factor.

In many instances, the standards listed above have been employed singly, not collectively. As a result, it has sometimes been assumed that successful support of one function implies adequacy in respect to another; protein capable of supporting growth, for example, is also efficient for body maintenance or for insuring successful reproduction and lactation. Such a premise may be questioned, and in this connection Morgan and Kern, in 1934, aptly suggested that the amino acids needed for adult maintenance may be quite different from those required for growth. The suggestion has found substantial verification in the investigations of Burroughs *et al.* (1940).

<sup>1</sup> Journal Paper No. J-912 of the Iowa Agricultural Experiment Station, Ames, Iowa, project No. 253. A preliminary report was presented before the meeting of the American Physiological Society at Cincinnati, 1933.

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In respect to reproduction and lactation, workers in the field have more or less generally taken for granted that the nitrogen requirements for the support of these functions are more complex than those of growth or maintenance. Whether this will prove true when all the prerequisites of a fully adequate diet are determined remains to be answered. Difficulties have arisen also because often, observations have been based on one reproductive cycle, or, at best, on those occurring in one generation of animals. To us, it seems that the criteria needed for the evaluation of the nutritive value of a diet must cover not only the needs of an individual throughout its entire life history but those of the species as well. An investigation described by Slonaker (1939) dealing with the effect of different percentages of protein in the diet of rats probably represents as comprehensive an attack of the problem from this angle as any reported to date.

In the present experiments, a series of four rations were formulated which we believed would test the efficiency of meat for maintaining all life functions when it serves as the main source of dietary protein. The rations were fed to groups of albino rats for periods long enough to demonstrate whether or not they were capable of supporting indefinite perpetuation of the species. Simultaneously, the diets were rated according to average growth, physical fitness, length of life, and reproductive efficiency of successive generations of the animals subsisting upon them.

In the present report, the breeding records of four groups of rats fed diets containing dried canned autoclaved beef or pork muscle at two levels of intake are presented. Results covering the ability of meat diets to support other life functions will appear in later papers.

#### EXPERIMENTAL

In general, the nutritive value of the four diets employed was assessed by determining the ability of groups of rats to maintain themselves for six generations. Sherman (1932) believes that a diet providing 10 to 15 per cent of its total calories as protein provides a liberal margin for safety insofar as the nitrogen needs of the individual are concerned. Therefore, a diet containing dried canned autoclaved pork muscle equivalent to 15 per cent of protein was formulated. In a second diet, the dried canned pork muscle was replaced by beef similarly prepared. Then, in addition, since we were interested in the effect of the ingestion of large quantities of meat, two other diets were planned in which the protein level was increased to 30 per cent by doubling the quantity of pork or beef at the expense of cornstarch. The two rations containing 15 per cent of protein were designated as Pork I and Beef I; the two, containing 30 per cent of protein as Pork II and Beef II. At the time of their formulation, it was believed that the diets contained all of the essential nutrients in sufficient quantities. Their composition is shown in Table 1.

The problems introduced by variations in the use of different samples of meat in the diet as the experiment progressed were recognized.

The use of fresh pork in the rations was precluded on account of the trichinosis that developed in rats in preliminary feeding trials. Since facilities for freezing were not available when the experiment was initiated, it was necessary to resort to the use of canned meats. Meat obtained from the Iowa Packing Company was canned in lots varying in size from 500 to 1,500 lb. The pork was purchased as green skinned hams, the beef in matched rounds. Before canning, the meat was closely trimmed of fat, and ground. Portions weighing 1 lb. were placed in cans which were sealed and processed for 65 minutes at 15 lb. pressure. When the cans were opened, the fat congealed on the top was removed and discarded. One thousand gm. of meat were then spread in a thin layer on a Monel metal tray covered with cheesecloth, and dried to one-half

TABLE 1  
COMPOSITION OF DIETS

Constituents	Pork I	Pork II	Beef I	Beef II
	<i>percentage</i>	<i>percentage</i>	<i>percentage</i>	<i>percentage</i>
Dried autoclaved pork muscle (dried to $\frac{1}{2}$ its original weight)	25	50		
Dried autoclaved beef muscle (dried to $\frac{1}{2}$ its original weight)				
Cornstarch	53	28	25	50
Yeast*	5	5	53	28
Agar agar†	2	2	5	5
NaCl	1	1	2	2
Osborne & Mendel salts	4	4	1	1
Butterfat	8	8	4	4
Cod liver oil‡	2	2	8	8
Protein value (N $\times$ 6.25)	15.25	26.28	2	2
			15.00	27.55

\* Yeast Foam Tablet Powder obtained from the Northwestern Yeast Co., Chicago, Illinois.

† Bacto-Agar purchased from the Difco Laboratories, Inc., Detroit, Michigan.

‡ Refined Norwegian vitamin tested cod liver oil, U.S.P., purchased from the Pearson Ferguson Co., Kansas City, Missouri.

the original weight under a current of warm air, in an oven kept below 100° C. Approximately 1 hour was required. This concentration was necessary for the adjustment of the protein values of the diets. The partially dehydrated meat was never stored, being incorporated in diets at once.

The diet was mixed twice weekly and stored in an ice box. A quantity of food slightly greater than the rat could eat was fed daily. The portion unconsumed at the end of the day was discarded.

The experimental animals used in making up the parental groups were albino rats of strain A, Wistar stock, inbred by brother and sister matings for 64 generations. The animals, weaned from the stock colony when 28 days old, weighed approximately 50 gm. The young rats, both males and females, were given the stock diet of the breeding colony until they were 56 days old. Then they received the experimental diet of the group to which they had been assigned. Rats in later generations never



had access to any but their specific experimental diets. The rats were housed separately in wire-mesh cages with raised screen bottoms. The pans were cleaned daily, cages and pans sterilized weekly. The daily food consumption was recorded.

In breeding, the brother-sister plan of mating was followed. In the early part of the experiment, a pair of animals 56 days old was caged together until the female became pregnant. Upon weaning of the litter, the same pair was re-mated. Toward the end of the study, the females were bred only when in heat, as determined by examination of cells removed from the vagina. In general, the reproductive histories to be described are those of pairs of animals. Only if a female persistently failed to give a positive mating was she mated with a different male; then another brother was used.

Every animal was given the opportunity to bear and rear six litters—a performance arbitrarily designated as highly satisfactory. In order to equalize lactation strain, large litters were reduced to six rats, 4 days after birth. Therefore, theoretically, in each generation a female had the opportunity to rear thirty-six young. However, the records reported herein of a group of rats maintained on the adequate ration fed the stock colony indicate that this standard may have been too high. The performance of this particular group of stock rats measured about two-thirds the criterion set. This point should be kept in mind in evaluating the data obtained in the experiment.

After the weaning or loss of the sixth litter, or when sterility was proved in less successful cases, the female and her brother mate were removed to the "longevity" colony where they were kept under the best conditions possible until death.

The group of rats transferred at weaning from the stock colony to the experimental diet was designated as the parental generation, following generations as generation I, generation II, etc. A precipitous loss in the weight of the maternal rat with or without the appearance of a litter was taken to indicate the birth of a litter, the latter situation being interpreted as cannibalism. A slow loss in body weight beginning about 14 days after the observation of a positive mating was termed a resorption.

In planning for the propagation of generations, it was necessary to devise a scheme whereby the number of rats produced could be kept within the facilities of the laboratory. Two pairs of rats, the average of the litter as to weight, were removed from either a second or third litter produced by a parental rat, to form generation I. In some cases where no second or third litters were reared, animals from the fourth litter were used for the first generation. The rats from all other litters were discarded at weaning. Similarly, from the second or third litters of each first-generation-female, another two pair of young were chosen for starting generation II. Thus, if she were 100 per cent successful, one parental female in six generations would produce fifty-two breeding females and 2,268 progeny.

## RESULTS

The average reproductive record in successive generations of females reared on each of the four test diets is shown in Table 2. Complete extinction of the species followed the feeding of the Pork I diet. Reproductive disaster beset the group very early in its history. Even in the parental generation, each female was able to rear only 6.2 young instead of the theoretical thirty-six. In many of these rats, also, an unusual syndrome appeared in the first or second gestation on the day of parturition. Seemingly in fine physical condition, the animals suddenly became moribund and in some cases, convulsive. In either case, the syndrome had many of the characteristics of a "toxic" pregnancy in the human being, and invariably ended in death. Its incidence was fairly high; of the animals observed to date, 43 per cent have developed the disorder in the parental generation.

The fertility of the rats that survived parturition was low, each female producing an average of only 3.0 litters, each containing 7.0 rats. About 24 per cent of the young were born dead, and of those born alive, 44 per cent were dead at the end of 4 days. Each female reared only 42 per cent of the young allotted to her after the litters were reduced to six rats. With the plan of breeding followed, approximately 325 days elapse under normal conditions from the time of initiation of the first pregnancy to the weaning of the sixth litter. Under the present experimental conditions, the reproductive period of the rats fed the Pork I diet was considerably shorter, being only 108 days.

Records in the first generation were poorer than in the parental group. Fewer litters were born per rat and the litters were smaller. On the average, each female weaned only 1.1 young. These young when bred were sterile, so the group became extinct with the second generation.

The substitution of the same quantity of beef for pork in the experimental diet effected very little, if any, improvement. Pregnancy disease still appeared, and the average reproductive behavior resembled that of the pork-fed rats. However, in this dietary group, rats of the second generation were not completely sterile.

An increase in the quantity of pork in the Pork I diet to a level approximating 30 per cent of protein (Pork II) improved the breeding records only to a slight extent in the parental generation, the most notable change being the drop in the incidence of "toxic" pregnancy. However, the relative number of resorptions per rat increased. Performance fell markedly in later generations, so that the group died out in the fifth generation.

Although the replacement of pork with beef at the lower level did not enhance the nutritional qualities of the diet, a most unexpected and surprising improvement occurred when beef supplanted pork in the diet containing 30 per cent of protein. A smaller proportion of the rats fed this

TABLE 2  
AVERAGE BREEDING RECORDS OF SIX GENERATIONS OF RATS FED DIFFERENT EXPERIMENTAL DIETS

Diet	Generation	No. of Rats in Each Group	Percent- age Inci- dence of Preg- nancy Dis- ease	Percent- age Inci- dence of Resorp- tions	No. of Young Born	No. of Litters	Average No. of Young per Litter	Percent- age of Young Born Dead*	Percent- age of Young Born Alive Dead at 4 Days	No. of Young Reared†	Percent- age of Young Reared†	Average Length of Repro- ductive Period in Days	Percent- age of Females Failing to Rear Young
Pork I	Parental.....	30	43.3	5.7	21.1	3.0	7.0	23.9	44.1	6.2	42.4	108.2	43.3
	I.....	16	0.0	4.6	6.4	1.4	4.5	15.5	68.2	1.1	24.1	64.8	81.2
	II.....	8	0.0	0.0	0.0	0.0				0.0		0.0	100.0
	III.....	0											
	IV.....												
Beef I	Parental.....	21	47.6	1.6	19.4	3.2	6.1	23.3	47.7	7.0	57.6	113.8	38.1
	I.....	33	0.0	23.8	3.3	0.5	5.5	28.9	58.1	0.8	35.6	25.3	84.8
	II.....	2	50.0	0.0	9.0	2.5	3.6	48.0	100.0	0.0	0.0	89.5	100.0
	III.....	0											
	IV.....												
Pork II	Parental.....	20	10.0	23.5	20.0	2.7	7.4	27.9	42.8	6.4	51.6	162.2	45.0
	I.....	18	0.0	17.3	5.3	1.0	4.8	8.5	68.3	0.7	28.9	52.4	88.9
	II.....	4	0.0	0.0	7.0	1.0	7.0	6.7	55.1	1.7	29.1	46.0	50.0
	III.....	3	0.0	14.3	11.7	2.0	5.8	19.0	66.2	4.0	33.3	98.3	33.3
	IV.....	4	0.0	37.5	12.0	1.5	8.0	8.3	67.5	4.2	47.2	92.7	50.0
Beef II	Parental.....	15	13.3	3.8	26.6	3.5	8.0	10.1	29.9	12.6	68.6	161.9	26.7
	I.....	32	3.1	4.3	18.9	2.9	6.5	19.9	44.5	7.3	52.4	124.4	40.6
	II.....	24	0.0	3.2	25.0	3.7	6.7	13.9	47.8	10.6	53.8	176.8	16.7
	III.....	28	0.0	2.9	26.7	4.0	7.1	14.3	51.3	10.4	52.0	168.5	15.4
	IV.....	36	0.0	2.7	20.8	2.9	7.1	12.7	30.6	10.4	65.6	147.5	27.8
Beef II	Parental.....	41	0.0	3.8	23.4	3.1	7.5	16.3	33.0	11.6	66.0	160.8	26.8
	I.....												
	II.....												
	III.....												
	IV.....												

\* In this study females were observed only at 24-hour intervals. These data, therefore, may be unduly high due to inclusion of young that died within the first 24 hours of life.

† Ratio: Total number of young reared  
Total number retained after  
litters were reduced to 6

ration developed pregnancy disease than when either the Pork I or Beef I diets were fed. Given the opportunity to produce six litters, the average female in the parental generation gave birth to 3.5. The litters were larger, so the total number of young born per female was higher than in the other records studied. These females on the average reared more young than did those in any other group. However, high mortality persisted in early infancy, suggesting that the vitality of the offspring born was not up to par. Of the young that survived to 4 days, a fair percentage was reared. Improved lactation was also indicated by the observation that 73.3 per cent of the females in the original parental group were now able to rear a litter—a performance in sharp contrast to that of the females fed either the Pork I or Beef I diets.

The most significant finding, however, is the fact that the pattern of reproduction set in the parental generation was maintained in the five later generations studied. The decrease in the number of litters born per female in the fourth and fifth generations suggested a lowering of fertility, but statistical analysis of the data did not support this conclusion. Notable, also, is the disappearance of toxic pregnancies.

The breeding efficiency of rats fed the four diets, as summarized in Table 3, clearly demonstrates the superiority of the ration containing 30 per cent of beef (Beef II). In this study each of the four parental groups was reduced to fifteen rats, litter mates being chosen insofar as possible in making up the dietary groups.

With the breeding plan described, the fifteen original Pork I, Pork II, and Beef I rats gave rise in later generations to only twenty-two, thirty-three, and seventeen breeding descendants, respectively, while the Beef II animals produced 141. The progeny of the first three groups numbered only 352, 528, and 209; those of the rats fed the high beef ration, 3,652. The last group reared well over six times as many young as any other. Approximately two-thirds of the litters reared met the arbitrary standard set, *i.e.*, six rats per litter.

The extent to which the performance of the Beef II-fed rats represented normal behavior was next determined by a comparison of their breeding records with those of a group maintained on the regular stock colony ration known as Steenbock V. In this study, records of five rats were analyzed in each generation. Every breeding female was a direct offspring of a rat studied in the preceding generation. Although it has been demonstrated that doubling the quantity of beef in the basal diet produces marked changes in its nutritive value, the ration still is not nutritionally complete (Table 4). In six generations, the group of Steenbock V rats gave birth to 1,153 young, a record about 37 per cent better than that of the Beef II group.

The general nutritive condition of the four groups of meat-fed rats in the first generation is interesting (Plate I). Individuals from all groups except the rats fed the Pork I diet seemed in good physical condition at the age of six months. The Pork I rat pictured does not show the extreme emaciation and debilitation that characterized many of these animals.

Except for the reproductive records, the groups fed the Beef I, Beef II, and Pork II diets would have been judged in equally good nutritive condition, showing the fallacy of making generalizations in regard to nutritional quality of diets from growth and maintenance data only.

The difference in the physical condition of the young suckled by the Pork I and Beef II rats was marked. The two pairs of young rats shown in the plate were each 12 days old. The young belonging to the pork-fed mother weighed 10 gm. each, those to the beef-fed rat, 28 gm. The con-

TABLE 3

PROPAGATION OF ORIGINAL GROUPS, EACH COMPOSED OF FIFTEEN PAIRS OF RATS, THROUGH SIX GENERATIONS WHEN FED FOUR DIFFERENT DIETS

Diet	Number Breeding Females Produced	Total Number of Young Born	Total Number of Litters	Total Number of Young Reared	Total Number of Litters Reared	Total Number of "Perfect"* Litters Reared
Pork I	22	352	64	92	17	11
Beef I	17	209	38	62	13	4
Pork II	33	528	79	165	32	21
Beef II	141	3,652	509	1,652	309	209

\* A litter of six.

trast between the offspring was not always as marked as that pictured, but differences in musculature, muscle tonus, and general physical development (note eyes and hair) were always apparent, and the mothers given the Beef II diet without exception reared the heavier young.

#### DISCUSSION

It has been demonstrated that complete reproductive failure characterized by sterility, loss of maternal rats at parturition in pregnancy disease, production of nonviable young, poor lactational performance, and sterility in the second or third generation follows the feeding to albino rats of a ration containing either dried autoclaved pork or beef muscle equivalent to 15 per cent of protein. At the time that the ration was originally formulated, it was believed that the response of the animals to the diet should serve as an index of the efficiency of meat as a source of dietary protein. However, before the nutritive failure can be ascribed even tentatively to the protein of the diet, the significance of certain data obtained in the course of the experiment must be considered. For example, it was found that dried canned beef muscle had unique nutritive properties not possessed by pork when each was fed at a level equivalent to 30 per cent of dietary protein. Did the additional beef add an assortment of amino acids specifically suited for reproduction, or did it supply essential vitamin factors, either old or new, missing in the rations con-



FIG. 1. Physical condition of mature rats (six months old) and of sucklings



taining 15 per cent of meat proteins? We felt that before these questions could be answered, it was necessary to re-examine the basal diets critically in terms of their adequacy in the known dietary essentials, especially since late developments in the field suggest the possibility of certain deficiencies. For instance, the effect of manipulative procedure on the nutritive value of various materials furnishing the dietary nutrients, the recently established high demands of the animal for certain of the better known essentials in reproduction and lactation, and postulations of the necessity of including newly identified nutrients in the theoretically adequate diet for the rat all emphasize the importance of such revaluation.

The basal pork diet (15 per cent protein) was chosen for re-testing. The checking of the ration has proceeded along three lines. First, with the demonstration that high temperatures may exert a detrimental effect

TABLE 4

NUMBER OF PROGENY PRODUCED BY RATS FED DIFFERENT DIETS FOR SIX GENERATIONS, EACH ORIGINAL GROUP COMPOSED OF FIVE RATS AND EACH SUCCESSIVE GENERATION COMPOSED OF FIVE DIRECT DESCENDENTS OF THE PRECEDING GENERATION.

Diet	Number of Young Born	Number of Litters Born	Number of Litters Reared	Number of Young Reared	Number of Perfect* Litters Reared
Arbitrary standard set	.....	180	180	1,080	180
Steenbock V	1,153	135	116	608	111
Beef II†	722	105	63	317	41

\* A litter of six.

† Records adjusted from data in preceding analysis to five rats in each group to make these data comparable to the records of the rats fed Steenbock V diet.

on the nutritive value of beef proteins (Morgan, 1934), it might well be that denaturation, in the present instance, had lowered the quality of the meat proteins, generally rated of high nutritive value (Jones, 1939). Therefore, the quality of the proteins in the meat ration was determined in a series of appropriate tests. Second, in view of the ease with which vitamins A and E are destroyed in the presence of rancid fat (Mattill, 1927, and Cummings and Mattill, 1931), the autoclaving also may have induced a sufficient rancidity of the meat fat to render the fat-soluble constituents in the dietary mix impotent. This possibility made assays of the diet for these essentials necessary. Third, the diet contained only 5 per cent of yeast. Recent researches (Sure, 1940) have suggested that this quantity of yeast in the diet may not supply adequate amounts of all members of the vitamin B complex for reproductive function. The diet has been assayed in this respect by increasing the quantity of yeast in the ration, and by supplementing the diet either with different foods

considered rich in the B complex or with its specific components as they became available for testing.

These experiments will be reported in later communications, but a brief summary at this time of the results obtained in the more important tests may be helpful to readers in the interpretation of the data herein presented.

The biological value of the proteins (meat and yeast) of the diet is 74. As will be noted later, a supplement of fresh liver in doses of 2 gm. per rat per day definitely better the reproductive performance. The biological value of the mixture of pork, yeast, and liver proteins was found to be 72. Therefore, the effectiveness of the liver supplement cannot be ascribed to an improvement in the quality of the dietary proteins. Certain amino acids, *i.e.*, cystine, methionine, and a mixture of cystine, glycine, and glutamic acid, when fed as dietary supplements, do not materially increase the nutritive efficiency of the diet.

The diet is adequate in the fat-soluble constituents, vitamin A, vitamin E, vitamin D, and vitamin K. Products produced by possible rancidity changes following the autoclaving of the meat apparently are not responsible for the dietary failure since the incorporation of rancid lard in the ration fed the stock colony does not change the normal picture to the one induced by feeding the basal pork diet.

The possibility that 5 per cent of yeast in the diet furnished an inadequate amount of the vitamin B complex for the needs of the animal under the conditions of this experiment does not seem tenable because increasing the quantity of yeast to 15 per cent brings about only a partial improvement in the reproductive performance in the parental generation. The beneficial effects are not as marked as those induced by doubling the beef protein in the basal ration.

To date only two dietary supplements, *i.e.*, liver (2 gm. daily) and one sample of lipocaic, Dragstedt's postulated pancreatic hormone (1936), have proved effective in preventing nutritive failure in rats fed the Pork I diet. The addition daily of 4 gm. of fresh pancreas, the source of lipocaic, produces some improvement. The protective factor in the liver seems labile since neither a frozen nor a heated product provides full protection. In fact, one fraction, particularly rich in the B vitamins, (Lilly liver extract, No. 343) increases the intensity of the disorders noted. It seemed that choline, whose role in fat metabolism has been elucidated by Best (1941) might be involved, since the feeding of the pork diet consistently produces fatty livers (Armstrong and Swanson, 1943). However, this substance when incorporated in the diet, also aggravates the nutritional disturbances characteristic of rats maintained on the basal pork diet. Additional riboflavin produces no beneficial effect.

The relative effectiveness of adding certain of the factors recently identified as members of the B complex, such as inositol, pantothenic acid, biotin, and para-amino benzoic acid is being tested at present. Inositol appears to be without value; biotin may exert some influence. This group of experiments is not yet completed.

The results, on the whole, obtained from these many tests indicate that the nutritional disturbance evoked by feeding the pork diet cannot be ascribed to a deficiency of any of the better known nutritional factors, protein or vitamin. The question as to whether one of the more recently identified food nutrients of the B group or an entirely new factor is needed for the support of reproduction and lactation is being pursued further. Also, the interrelationship of various vitamins and their influence on the nutritional picture must be considered. The difficulties introduced in the solution of the problem by the complex nature of the meat are recognized.

#### SUMMARY

1. The respective breeding records of four groups of rats maintained, when possible, for six generations on supposedly adequate diets containing partially dehydrated canned autoclaved pork or beef muscle incorporated in the rations in quantities equivalent to either 15 or 30 per cent of protein have been studied.

2. Complete reproductive failure characterized the response of the group fed the diets containing either beef or pork equivalent to 15 per cent of protein. These diets, then, cannot be classed as nutritionally complete, although they, theoretically, carried all the essential food nutrients known at the time the experiment was initiated. However, experiments designed to check the adequacy of the basal pork diet have not furnished evidence to date that the ration is deficient in the recognized food nutrients.

3. Increasing the quantity of pork in the diet effected very little improvement in the response of the rats. On the other hand, the diet containing 30 per cent of protein in the form of dried autoclaved beef supported life over six generations. At the end of that period, with the plan of breeding used, the fifteen rats composing the original group were represented by 3,653 progeny in contrast to 528 produced by a similar group of rats fed the high-pork diet. Beef, therefore, possesses certain nutritive qualities not characteristic of pork.

4. Although the study was originally planned to study the rôle meat may play in the nutrition of the rat when it serves as the chief protein constituent in an experimental ration supposedly adequate in all the essential nutrients, it did not contribute information to that end. Instead, the investigation has furnished data that support the hypothesis that there is a specific food nutrient that is pre-eminently important in the control of normal reproductive function. This nutrient is present in a limited amount in beef muscle.

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# REDUCTION IN THE EFFICIENCY OF ABLASTIC ACTION IN TRYPANOSOMA LEWISI INFECTION BY WITHHOLDING PANTOTHENIC ACID FROM THE HOST'S DIET

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The effect of the various known vitamins in the host's ration upon parasite population is a problem that has occupied the interests of a number of investigators. Vitamins B<sub>1</sub>, B<sub>6</sub>, and pantothenic acid have proved of special interest in our laboratory because of the marked effects they have been shown to exert upon the number of oocysts eliminated by rats infected with the protozoan parasite *Eimeria nieschulzi*. Among the most striking of the effects observed were reduced yields of oocysts when the ration was supplemented with both vitamin B<sub>1</sub> and vitamin B<sub>6</sub> and otherwise somewhat submarginal in vitamin values (Becker and Dilworth<sup>1</sup>), and increased yields when pantothenate was supplied in addition to these two vitamins (Becker and Smith<sup>2</sup>). Since the coccidium is an inhabitant of the epithelium of the intestinal mucosa, it seemed that a study of the possible effects of the three vitamins on a blood-inhabiting protozoan would present an interesting comparison.

*Trypanosoma lewisi* was the logical choice for such a study, not only because it is the only blood-inhabiting protozoan of rats that is readily available, but also because its development in the rat host has been so accurately delineated (Taliaferro and Taliaferro<sup>3</sup>). The course of an infection involves, first, an incubation period of up to 3 days during which the flagellates are not demonstrable in the blood; second, a period of multiplication lasting to about the tenth day, characterized by increasing numbers of the parasites, binary fission, and notable variability in size and form; third, a "crisis," followed by an abrupt decline in numbers of the parasites, practical absence of fission, and a high degree of uniformity in size and form; fourth, a period of adulthood lasting until the termination of the infection, a variable period, sometimes lasting until the hundredth day or longer; and finally, the total extinguishment of the infection and immunity to reinfection. The inhibition of reproduction is attributed to the formation of an antibody, ablastin; the extinction of trypanosomes to a trypanocidal antibody (*Vide* Taliaferro<sup>4</sup>). Against such a background any observed effects of vitamin feeding on the population could be subjected to some degree of analysis.

## MATERIAL AND METHODS

The strain of *Trypanosoma lewisi* employed was one that appeared spontaneously in a rat colony on this campus. It differs from most strains

<sup>1</sup> Jour. Inf. Dis. 68:285, 1941.

<sup>2</sup> Ia. St. Coll. Jour. Sci. 16:443, 1942.



of its species in that the population in the blood of the infected rat does not attain anywhere near the levels reached by the others. This belief was confirmed by comparison with a strain secured from the laboratory of Dr. W. H. Taliaferro at the University of Chicago. It was ascertained, however, that immunity to either strain confirmed on the host immunity to the other. Inoculation was by the intraperitoneal injection of 1 cc. of diluting fluid containing from 20,000 to 40,000 trypanosomes.

The host was the highly inbred Wistar A rat. Litters were started on the basal ration as they approached a mean weight of 70 gm. Feeding of supplementary vitamins to the test animals was not started till the eighth day. The entire preparation period preceding the date of infection was 14 to 15 days. In every test the groups were derived from the same litter which was divided as equally as feasible in respect to sex and weight into two or three groups, as desired.

The "basal" ration consisted of the following materials in parts by weight: dry-heated commercial casein, 20; dry-heated gray shorts (of wheat), 10; beet sugar, 61; salt mixture (Harris), 4; lard, 4; cod-liver oil, 1. Materials to be dry-heated were distributed in thin layers in shallow pans and placed in an electric oven which we tried to maintain at about 110°–115°C. for 6 full days, though at times the temperature somewhat exceeded the higher figure. Both casein and shorts were noticeably browned. Such a process is known to destroy pantothenic acid in foods (Kline, Keenan, Elvehjem, and Hart<sup>5</sup>), and probably also vitamin K (Ansbacher<sup>6</sup>), though the latter vitamin appears to be less important in rat nutrition than the former. Vitamin B<sub>1</sub> was employed as the synthetic crystalline thiamin chloride. Vitamin B<sub>6</sub> was in the form of the synthetic crystalline pyridoxine hydrochloride. The pantothenate was the synthetic crystalline calcium pantothenate. The vitamins were administered every other day in aqueous solution directly into the rat's stomach through a soft rubber catheter in amounts as follows: thiamin chloride, 50μ; pyridoxine, 100μ; pantothenate, 100μ.

Trypanosome counts were made by a method similar to that employed by Morrell, Chapman, and Allmark<sup>7</sup>. The blood was drawn from the end of the tail, and measured and mixed with diluting fluid in blood-diluting pipettes. The diluting fluid consisted of the following dissolved in 100 cc. of distilled water: sodium citrate, 1.0 gm.; sodium chloride, 0.75 gm.; glucose, 0.20 gm. Counts were made in a Levy-Hausser haemocytometer with the high-dry lens of the microscope. In general the practice was to make the first count when the numbers in the blood reached a level where counting was practicable, and every other day thereafter.

Following Taliaferro and Taliaferro<sup>3</sup> in their earlier work, we have employed the coefficient of variation as an index to the rate of reproduction of the trypanosomes. The standard deviation was computed from measurements of the entire length of 50 trypanosomes, with 50 as the

<sup>5</sup> Am. Jour. Hyg. 2:264, 1922.

<sup>6</sup> Am. Jour. Hyg. 16:32, 1932.

<sup>7</sup> Jour. Biol. Chem. 99:295, 1932.

<sup>8</sup> Proc. Soc. Exp. Biol. and Med. 44:248, 1940.

<sup>9</sup> Am. Jour. Hyg. 25:232, 1937.

value of  $n$ . In a few cases, however, it was not possible to find 50 on a slide, so that in these few cases it was necessary to reduce the number measured to 25.

#### EXPERIMENTAL DATA

We are reporting in this paper only the detailed results of four experiments, summarized in Table 1. There was, in addition to these, a preliminary series of tests in which the casein and shorts were heated in the range of 100°–110°C. for 6 days. The results of these were conflicting, and for this reason are being omitted from this presentation, though they did serve to suggest that the marked reproduction of the trypanosomes in certain of the tests might be due to the combination of vitamin B<sub>1</sub> and vitamin B<sub>6</sub> supplements and lowered pantothenate content of the ration owing to heating. It now seems altogether possible that, for the rat, at least, the amount of pantothenate left in the ration after heat treatment at 100°–110°C. is near marginal for its requirements, which would account for the failure to get consistent results. The four tests with casein and shorts heated in the 110°–115°C. range for 6 full days gave such consistent results that one would appear justified in assuming that these temperatures brought about considerably greater destruction of pantothenate than the lower.

It is obvious from an inspection of Table 1 that the trypanosome counts in the rats which received the supplement of only vitamins B<sub>1</sub> and B<sub>6</sub> were as a rule higher on the ninth day of the infection. In addition, they generally persisted at the high numerical level for a considerable length of time before a marked decline occurred. In the case of rats 1–5, Experiment 1, each successive count was higher until the thirteenth day, though even on that date it was higher for rats 1, 4, and 5. The coefficients of variation computed at the times of the counts indicate that reproduction was proceeding in these rats up until death in three cases, until the twenty-second day in one case, and the nineteenth day in another. The infection in the recipients of pantothenate took quite a different course, with few flagellates appearing in the blood of rat 9 only on one, the seventh, day; in rats 6 and 7 only in the fifth, seventh, ninth, and tenth days; and moderate numbers for a considerable length of time in rats 8 and 10. In each of rats 6–10, the trypanosomes arrived at a high uniformity of length, as indicated by the low coefficients of variation, i.e., near or just below 5 per cent, on either the ninth or eleventh day.

The trypanosome counts and coefficients of variation for rats 11, 12, and 13 of Experiment 2 took, in general, courses similar to those for rats 1–5 of Experiment 1, with death supervening in the case of rats 11 and 13. The population levels reached in rats 14 and 15 were more modest, though high as compared with the controls (rats 16–20). The coefficient of variation for the trypanosomes in rat 14 fell to 3.7 on the seventeenth day, while that for rat 15 sank to 3.2 on the thirteenth day. Of the recipients of pantothenate, rats 16–20, rats 17 and 18 did not become heavily enough infected to make counting practicable. Attempted reinfections on the tenth day after inoculation were negative. Rats 16, 19, and 20 developed

very light infections of short duration. In these three cases the coefficient of variation reached the low level indicative of adulthood by the eleventh day.

Experiment 3 was an attempt to detect possible effects of omitting all vitamin supplements (rats 21-23), omitting B<sub>1</sub> and B<sub>6</sub> supplement but feeding pantothenate (rats 24-26), or of feeding B<sub>1</sub> and B<sub>6</sub> and omitting pantothenate (rats 27-29). Curiously enough, the coefficients of variation for all six rats of the first two groups had dropped to the low levels indicative of practical cessation of reproduction by the eighth day, and the population of the flagellates in the blood remained at low levels. In only one rat, No. 24, did the infection persist for more than 26 days. The picture in rats 27-29 was typical of what had been observed in Experiments 1 and 2, with enhanced parasite population and an extended period of reproduction, except for rat 28 which showed positive for the flagellates on only three examinations on the fourth, sixth, and eighth days. The value of 15 per cent for the coefficient of variation on the sixth day indicates that the trypanosomes were reproducing efficiently, but that trypanocidal factors were exceedingly active in this animal despite the kind of diet.

In Experiment 4 there was likewise a series (rats 30-33) which received no vitamin supplements and a series (34-37) which received vitamins B<sub>1</sub> and B<sub>6</sub>. Save for rat 35, which reacted much like rat 28 in Experiment 3, the recipients of vitamins B<sub>1</sub> and B<sub>6</sub> all developed much higher levels of parasite population than did the non-recipients, and the infections lasted longer. No measurements of the trypanosomes were made, but it was obvious from an examination of blood smears made on the ninth day that fission had ceased in rats 30, 31, 33, and 35, but was still proceeding in rats 34, 36, 37.

The effect of the infections on the rats is naturally one of interest in experiments of this kind. Since the trypanosome infections were heavier and the reproductive period of the trypanosomes longer in the rats of Experiments 1 and 2, a brief summary of the effects of these infections upon the rats is presented here. Records of the weight of rats 6-10 and 16-20 show that these animals made steady gains in weight, as attested by a mean of 71.8 g. at the start of experimental feeding and 154.3 at the time they were sacrificed, the twenty-second day of the infection. Of rats 1-5 and 11-15, five died before the experiment would have been terminated—the twenty-second day of the infection. The ration of these ten rats was, of course, deficient in pantothenic acid. Nevertheless, their mean weight increased 16 grams during the 15-day feeding period preceding the date of inoculation, and steadily thereafter until by the twelfth day of the infection it had increased another 23 g. By another 2 days one rat had died, and seven of the remaining nine lost weight, the losses running from 1-6 grams. By still another 2 days each surviving rat was again approximately at the level of the twelfth day or higher, except two which subsequently died.

The blood of the more heavily infected rats presented an altered picture. Before the infective date, rats 1, 4, 11, 14, 6, 9, 10, and 18 were selected at random for differential leucocyte counts. These were made on

TABLE 1  
NUMBER OF TRYPANOSOMES, IN THOUSANDS, PER CUBIC MILLIMETER OF BLOOD AND COEFFICIENT OF VARIATION (IN PERCENTAGE) FOR INDIVIDUAL TRYPANOSOME LENGTHS FOR INFECTIONS IN RATS INVOLVED IN FOUR EXPERIMENTS  
EXPERIMENT 1

Rat No.	Vitamin Supplement	Kind of Data	5th Day	7th Day	9th Day	11th Day	13th Day	15th Day	17th Day	19th Day	22nd Day	Remarks
1	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	24.2 24.5	385.5 17.6	570.0 4.5	606.6 19.4					Died on 13th d.
2	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.3 16.4	36.7 23.2	343.2 16.1	540.0 14.1	372.6 13.8	796.8 9.5				Died on 16th d.
3	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.4	22.2 17.7	129.2 23.8	347.0 11.8	229.0 9.1	406.0 10.2	421.2 8.2	228.0 7.5		Counts discontinued 19th d. Measurements discontinued 22nd d.
4	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.3 14.8	8.4 15.3	100.0 19.7	225.5 12.5	344.0 11.5	218.0 6.3	248.3 7.1	237.0 5.2	2.95	Counts discontinued 19th d. Measurements discontinued 22nd d.
5	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.1 21.3	11.0 17.3	86.4 26.6	438.0 27.0	466.2 26.3	391.3 8.0				Died on 16th d.
6	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	+	1.6 4.9	0.8 3.2	+	—	—	—	—	—	Spontaneous cure
7	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	+	1.3 4.7	1.0 3.0	+	—	—	—	—	—	Spontaneous cure
8	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	0.1	15.6 14.5	5.4 21.9	27.7 3.0	22.2 5.4	31.6 3.6	12.9 4.0	5.5 2.6		Counts discontinued 19th d. Measurements discontinued 22nd d.
9	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	—	+	—	—	—	—	—	—		Spontaneous cure
10	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	+	8.4 17.0	6.2 15.8	10.0 4.14	9.2 3.6	6.0 3.4	5.4 3.7	2.7 4.0	4.8	Counts discontinued 19th d. Measurements discontinued 22nd d.

TABLE 1—Continued  
EXPERIMENT 2

Rat No.	Vitamin Supplement	Kind of Data	5th Day	7th Day	9th Day	11th Day	13th Day	15th Day	17th Day	19th Day	22nd Day	Remarks
11	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.2 14.9	4.1 16.4	46.6 17.1	236.5 22.1	358.8 16.8	485.0 14.1	500.0 20.9	.....	.....	Died on 18th day
12	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	0.2 14.1	2.6 24.7	25.2 18.8	76.0 13.6	73.5 9.6	82.0 7.3	40.0 4.1	..... 2.5	Counting discontinued 19th d. Measurements discontinued 22nd d.
13	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	1.2 18.5	13.0 21.7	141.0 24.5	493.0 18.3	.....	.....	.....	.....	Died on 14th d.
14	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	0.5 20.0	5.2 15.0	11.2 13.0	2.6 7.5	5.3 5.6	4.4 3.7	3.4 3.6	..... 2.7	Counts discontinued 19th d. Measurements discontinued 22nd d.
15	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	2.0 17.5	8.6 11.6	14.0 6.9	5.7 3.2	7.2 2.9	6.9 3.5	8.5 3.7	..... 3.4	Counts discontinued 19th day Measurements discontinued 22nd d.
16	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	+	0.7 4.43	+	.....	.....	.....	.....	.....	.....	Spontaneous cure
17	B <sub>1</sub> , B <sub>6</sub> , P.A.	No tryps. C. V. (%)	+	+	+	.....	.....	.....	.....	.....	.....	Spontaneous cure
18	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	.....	.....	+	.....	.....	.....	.....	.....	.....	Spontaneous cure
19	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	0.1 16.0	2.5 16.3	1.8 18.4	1.2 3.98	0.2 5.14	.....	.....	.....	.....	Spontaneous cure
20	B <sub>1</sub> , B <sub>6</sub> , P.A.	No. tryps. C. V. (%)	+	0.7 22.3	0.4 12.7	0.3 5.1	+	.....	.....	.....	.....	Spontaneous cure

TABLE 1—Continued  
EXPERIMENT 3

Rat No.	Vitamin Supplement	Kind of Data	4th Day	6th Day	8th Day	10th Day	12th Day	14th Day	16th Day	18th Day	25th Day	29th Day	35th Day	65th Day	Remarks
21	None	No. tryps. C. V. (%)	0.5 16.0	9.1 18.0	4.8 4.1	3.9 4.3	3.2 3.81	2.4 3.6	1.8 3.7	2.0 1.31	5.0 3.9	.....	.....	.....	Spontaneous cure
22	None	No. tryps. C. V. (%)	0.2 21.9	10.2 13.8	3.5 5.1	4.2 5.2	5.6 4.8	3.2 4.2	1.1 3.8	+	+	.....	.....	.....	Spontaneous cure
23	None	No. tryps. C. V. (%)	0.3 17.7	2.1 8.3	0.4 5.6	0.3 5.8	0.2 5.0	.....	.....	.....	.....	.....	.....	.....	Spontaneous cure
24	P. A.	No. tryps. C. V. (%)	0.5 22.5	5.4 17.5	4.3 3.6	6.6 3.7	4.1 5.1	3.6 4.1	2.8 4.3	0.8 4.6	1.8 4.7	0.8 3.8	0.6 3.4	0.3 2.8	Infection lasted 70 d.
25	P. A.	No. tryps. C. V. (%)	0.1 6.7	0.2 8.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	P. A.	No. tryps. C. V. (%)	+	1.8 20.1	1.3 4.9	1.9 4.1	0.9 4.3	.....	.....	.....	.....	.....	.....	.....	.....
27	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	0.1 19.2	8.0 12.3	13.6 9.0	17.8 4.5	21.2 4.1	11.2 3.2	16.5 3.2	16.8 1.5	18.4 4.9	5.0 3.7	4.1 4.2	Infection lasted 105 d.
28	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	+	0.2 15.2	+	.....	.....	.....	.....	.....	.....	.....	.....	.....	Spontaneous cure
29	B <sub>1</sub> , B <sub>6</sub>	No. tryps. C. V. (%)	0.2 16.6	18.7 22.1	88.2 18.7	99.1 14.4	100.4 8.6	121.0 6.2	117.0 5.4	77.0 4.2	65.0 3.1	49.0 2.8	36.0 2.5	22.8 3.8	Infection lasted 123 d.



TABLE 1—Continued  
EXPERIMENT 4

Rat No.	Vitamin Supplement	Kind of Data	5th Day	7th Day	9th Day	11th Day	13th Day	15th Day	17th Day	19th Day	25th Day	Remarks
30	None	No. tryps.	+	0.2	1.4	1.3	1.8	0.7	0.3	—	—	Spontaneous cure
31	None	No. tryps.	+	0.3	0.8	0.8	+	—	—	—	—	Spontaneous cure
32	None	No. tryps.	—	—	—	+	—	—	—	—	—	Spontaneous cure
33	None	No. tryps.	+	0.3	1.8	2.4	1.5	1.3	0.6	0.3	—	Spontaneous cure
34	B <sub>1</sub> , B <sub>6</sub>	No. tryps.	+	0.4	13.2	56.0	62.6	108.0	117.0	87.3	48.0	Spontaneous cure about 96th d.
35	B <sub>1</sub> , B <sub>6</sub>	No. tryps.	—	—	+	—	—	—	—	—	—	Spontaneous cure
36	B <sub>1</sub> , B <sub>6</sub>	No. tryps.	—	0.2	1.5	3.0	7.5	6.4	3.1	+	—	Spontaneous cure
37	B <sub>1</sub> , B <sub>6</sub>	No. tryps.	+	0.3	12.0	44.6	71.6	96.0	140.0	59.4	61.7	Spontaneous cure about 106th d.

the following dates: a week before inoculation, the date of inoculation, the fifth day of the infection, the thirteenth day of the infection, and in the survivors, on the twenty-first day of the infection. These data are not being presented here in detail, principally because we intend to make a much more thorough study of this phase of the problem later. There was, in rats 1, 4, 11, and 14, a drop in lymphocytes from 69.5–85.0 per cent on the first count to 35.5–52.0 per cent on the fourth and fifth counts, using figures for the fourth count in rats that died and for the fifth count in the survivors. At the same time, the neutrophil counts rose from 7.9–21.0 per cent to 42.0–57.5 per cent on the same dates. The corresponding data for rats 6, 9, 10, and 18, all recipients of pantothenic acid, were as follows: for lymphocytes a drop of 73.5–89.6 per cent to 60.5–83.0 per cent; for neutrophils, a rise from 5.0–14.0 per cent to 15.5–30.0 per cent. It is obvious that the effects on the differential leucocyte count were markedly more pronounced in the case of the rats which received vitamins B<sub>1</sub> and B<sub>6</sub> but no pantothenate. No blood studies were made on the remaining rats.

#### DISCUSSION

The strain of *T. lewisi* which was employed in the experiments described above is one which does not ordinarily attain a dense population in the blood of the white rat. We have repeatedly observed sparse experimental infections in rats raised on the well-balanced stock ration with which the colony is maintained. The trypanosome counts for six such white rats infected with about 40,000 of this strain ranged from 8–40 thousand per cmm. on the ninth day. In contrast, 6 rats infected with a strain received from the laboratory of Dr. W. H. Taliaferro gave counts ranging from 150–420 thousand on the same day. The sparse counts for the rats of Experiments 1 and 2 which received pantothenate and vitamins B<sub>1</sub> and B<sub>6</sub>, as well as those of Experiments 3 and 4 which received no vitamin supplement or only pantothenate, also testify to the high resistance of the host against this strain of *T. lewisi*. The ability of the trypanosome to multiply in the rat cannot be questioned, however, for in many cases, such as in rats 8, 10, 19, 20, 22, 24, etc., the values for the coefficient of variation reached moderately high levels. In every case among rats 6–10, 16–20, and 21–27 either the infection was terminated or the coefficient of variation reached the low level of around 5.0 per cent or lower, which indicates cessation of reproduction and adulthood, by the tenth or eleventh day.

It is obvious that severe restriction of pantothenate in the regimen of rats receiving liberal supplement of vitamins B<sub>1</sub> and B<sub>6</sub> resulted in the parasite attaining significantly higher population densities in the circulating blood. Is this phenomenon, which appears on the surface at least to be owing to decrease in the host's resistance, attributable to loss in efficiency of ablastin production, or to partial failure of the trypanocidal antibody? Considering the former possibility first, the coefficients of variation derived from the measurements of the flagellates from these rats tell the

story of an extended reproductive period, lasting up to the nineteenth day. Thus it is certain that the efficiency of ablastic action was interfered with, whether by interference with the production of ablastin or by the acquirement on the part of the trypanosomes of an unusual degree of vigor enabling them to continue reproduction for a while in the face of the accumulating concentration of ablastin. On the surface at least, the shorter duration of the infections in the rats in which the coefficient of variation of trypanosome size sank to "adult" levels on the tenth or eleventh day seems to argue for decreased trypanocidal activity as well as decreased ablastic action in the rats with the higher flagellate counts. It has been confirmed several times, however, that commencing the feeding of pantothenate early in "adulthood" will not depress the numbers of trypanosomes in the least.

It is to be recalled that Taliaferro, Cannon, and Goodloe<sup>8</sup> have reported that splenectomy in young *T. lewisi*- and *Bartonella*-infected rats, when performed on the day of infection or 5 to 10 days later, extended the reproductive phase of the trypanosomes or caused it to recur. Similar results with some variations were obtained in older rats also. Splenectomy of young, healthy, *Bartonella*-free rats, however, did not affect the length or character of the reproductive phase. Thus *Bartonella*-infection became intercurrent in the trypanosome infection when the restraining action of the host's natural defense against *Bartonella* was rendered defective by splenectomy. Taliaferro *et al.*<sup>8</sup> also showed that removal of the spleen influences the formation of the trypanocidal antibody, particularly in *Bartonella*-infected rats.

It is possible that we also have influenced the course of the trypanosome infection by releasing a *Bartonella*-infection from normal restraints in the host, except that we employed dietary rather than operative methods. There is a great deal of positive evidence that such is the case. In the first place, *Bartonella*-like bodies were frequently seen in the blood smears of the rats with the modified infections; secondly, the differential leucocyte counts previously described were indicative of *Bartonella*-infection; and, thirdly, the ratios of a number of spleen and body weights fell somewhere between the values which Taliaferro *et al.*<sup>8</sup> (p. 28) give for "rats infected with *Bartonella*, but not *T. lewisi*," and "rats infected with both *Bartonella* and *T. lewisi*." If our success in modifying the course of *T. lewisi* infection could be attributed to intercurrent *Bartonella*-infection, then the enhanced numbers of trypanosome in the host's blood will have to be considered of pathognomonic rather than pathogenic significance. If so, the deaths of certain of the rats would have to be ascribed to bartonellosis rather than trypanosomiasis.

#### CONCLUSIONS

1. The trypanosome population in *Trypanosoma lewisi* infection can be markedly increased by supplementing the regimen of the host with liberal amounts of vitamin B<sub>1</sub> and vitamin B<sub>6</sub>.

<sup>8</sup> Am. Jour. Hyg. 14:1, 1931.

2. The increased population is largely attributable to a decrease in the efficiency of the action of ablastin, the trypanosome-reproduction inhibiting antibody manufactured by the rat.

3. There appears also to be a decrease in the effectiveness of the trypanocidal reaction of the host, but this may be illusory.

4. The available evidence strongly suggests that intercurrent Bartonella-infection may be responsible for both the altered behavior of the trypanosome, death, and other pathologic consequences.

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THE PSYLLIDS OF AMERICA  
NORTH OF MEXICO (PSYLLIDAE: HOMOPTERA)

(Subfamilies Psyllinae and Triozinae)

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## INTRODUCTION

The psyllids, sometimes called jumping plant lice, are small homopterous insects constituting the family Psyllidae. They resemble the plant lice or aphids in many respects but may be distinguished from them by the stout legs which are adapted for leaping, the presence of nine or ten segments in the antennae (three to six in the aphids), the greater sclerotization of the exoskeleton, and the venation of the wings which, although somewhat variable, is quite unlike that of the aphids.

Although much interest exists concerning those species which are of economic importance, taxonomic work in the group has been sporadic since the publication, in 1914, of Crawford's monograph of the forms known to occur in the Western Hemisphere. Numerous new forms have been described since that time in scattered articles. This presentation is an attempt to incorporate the known data, other than that of purely economic import, of all the forms of the two principal subfamilies known to occur in America north of Mexico. It is hoped that it will be of interest and value not only to insect taxonomists but also to all those who are interested in these insects for any reason.

## HISTORICAL RESUME

In 1851 Fitch described six species of psyllids from the state of New York. This is apparently the first definite record of the occurrence of these animals in North America. The following year Walker, in his List of the Homopterous Insects of the British Museum, listed Fitch's species, several more of Fitch's manuscript names, and added one new species from Hudson Bay. Provancher added three names to the list in 1872. In 1890 he described six species as new, then in the Errata and Corrigenda of the same volume made two of them synonyms of his older species. Unfortunately, he had the genera confused. Although one can almost be positive of what his genera really were, the specific descriptions are almost entirely of the coloration except for characters which are of only generic or family significance. Until his specimens can be seen (if they are still extant), his names must remain *nomina inquirenda*. Beginning in 1876 C. V. Riley published various articles on Psyllidae intermittently for the next fifteen years, describing several new genera and species. Various workers added a few names to the growing list of species known from

North America until, when Mally published a list of all such in 1894, a total of thirty-one species was listed (several of these have since proved to be synonyms). The first worker in this country to take an active interest in other than North American forms was Schwarz, who made a few contributions to the knowledge concerning this group in other parts of the world as well as describing several new forms from this continent.

About 1910 two workers, who were to add a great deal to our fund of knowledge of the psyllids, became interested in this family. The first of these was Patch, who described numerous species, noted the life history of several, and worked out the wing venation, homologizing it with the venation in other Homoptera and applying the Comstock-Needham system of nomenclature to the veins. The second was Crawford, who culminated several years of very active work with his Monograph of the Jumping Plant-Lice or Psyllidae of the New World in 1914. In this paper he revised the subfamily classification. As far as the North American genera are concerned at least, this classification appears to be valid for the most part, and it is followed here without exception, as the possible misinterpretations are in those subfamilies which are largely exotic and with which the author is not familiar. Crawford continued active work in the field until quite recently, but as soon as he removed to Hawaii most of his interest devolved to the Pacific fauna.

Numerous contributions have been made since Crawford's work, notably by Ferris, Klyver, Van Duzee, and Caldwell. The forms of economic importance have, of course, received a great deal of attention, especially the pear psylla (*Psylla pyricola* Förster) and the potato psyllid (*Paratrioza cockerelli* (Sulc)). A very voluminous literature has developed about these two species.

## GENERAL DISCUSSION

### MORPHOLOGY

The first extensive work on the structure of the Psyllidae was that of Witlaczil who in 1885 published his *Die Anatomie de Psylliden* (reviewed by Macloskie, *Am. Nat.* 20, 1886), treating not only the external anatomy but also the internal structure, with especial emphasis on the nervous system. Stough, 1910, published on *Pachypsylla celtidis-mamma* at some length, but as this species is one of the more specialized and was studied without a background of the generalized species, his interpretations are somewhat erroneous. As is mentioned above, Patch determined the homologies of the wing veins in 1909.

Crawford's work on the external morphology remains as the most complete and thoroughly done. With a few changes in terminology, his interpretations are followed by the author. The figures explanatory of the morphology are adapted from those of Crawford (Figs. 2, 3, 4, 5, and 6).

The structure of the nymphs has received comparatively little attention. Mally described and figured a few in 1895. Ferris has published

several papers on various species. He started a series in which he planned to study the nymph of the type of each genus; this was subsequently turned over to Klyver and unfortunately seems to have been abandoned.

As this family is of world-wide distribution and is quite highly evolved, great variation in structure occurs, and considerable work remains to be done in homologizing and interpreting structures both within the family and with other Homoptera.

#### BIOLOGY

The biology of the forms in this family has received but desultory interest for the most part. Notes on observations of time of emergence of adults, egg-laying, appearance of nymphs, gall formation, etc., make up the bulk of our knowledge. The complete life cycle of several species has been worked out, however; Ashmead (1881) being the first to give such data for some of his species. Among others who have recorded some complete life cycles are Mally, Ferris and Hyatt, and Caldwell. The biology of the economically important species has, of course, been studied extensively, and most of their life cycles are known in detail. Much more life history work needs to be done, as much of the taxonomic work is, and shall remain quite uncertain until biological evidence such as the amount of variation within a species, the degree of host specificity, etc., is known. This is especially true in *Aphalara*, *Aphalaroida*, and certain complexes of *Trioza* and *Psylla*.

The most common life cycle finds the adult as the overwintering stage, the eggs deposited singly on the foliage of the host plant in the spring, one or more generations developing through the summer. Several species, however, overwinter as nymphs, emerging as adults late the following spring. This variation in life cycle occurs between members of the same genus.

The coloration of both nymphs and adults is quite variable as has been noted by all who have worked on these insects. Löw, Mally, Froggatt, Patch, Caldwell, and others have remarked on this variation and noted that it occurs among individuals of the same age and brood and that there is no correlation between the amount of pigmentation in the nymph and the adult.

Without known exception the members of this family are plant feeders, sucking the sap and cell contents from their hosts. The great majority live upon trees and shrubs. Some occur on herbaceous plants of various kinds other than grasses (Gramineae). There are a few that develop on *Juncus*, however.

The feeding of the nymphs of many species causes the production of galls or pseudogalls on their hosts. Among the more remarkable gall-formers are the pachypsyllids—the entire genus produces galls on the leaves, twigs, or branches of *Celtis* spp. (hackberries). In most of the other genera occasional species cause gall formation. Some species, not-

ably *Paratrioza cockerelli*, apparently inject a toxic material into the host plant, thereby causing a physiological disturbance, an insect disease.

The different species vary markedly in the amount of host specificity which they exhibit, some being limited to a single species and others developing on a number of hosts of various degrees of relationship. The adults seem to be able to maintain themselves on a wider variety of plants than the immature stages. At least a few species apparently have a definite alternation of hosts between the nymphal and imaginal stages, although the adult host range does not seem to be as limited as it is in many of the aphids which exhibit the same type of relationship. Because of the variability in the feeding habits of the adults, no plants are recorded in the following pages as hosts unless it is quite certain that the nymphs develop thereon. The literature of this group is full of references to hosts many of which seem to have been merely plants on which adults were resting at the time of collection. All recorded host records are, therefore, disregarded unless there is some evidence given that the plant named as host actually supports the developmental stages. Unfortunately, such discrimination has not always prevailed, and thus we have species named for plants which are not hosts at all.

The production of honey dew and of wax is general throughout the family. Many of the nymphs secrete large quantities of wax which may occur as a filamentous or a powdery deposit. Some of the adults also secrete wax but usually in less abundance.

#### COLLECTING AND PRESERVING

The psyllids are commonly overlooked by most collectors due in part to their small size but even more to their habits when swept up in a net. For several minutes after being thus captured, most of the specimens remain quiet in any debris which may be present in the net. Their first activity is usually to jump from the net in two or three leaps. This type of action causes them to be very easily missed.

As most of the species occur on trees and shrubs and many cling very tightly to the host, the ordinary type of sweeping often fails to dislodge them. Beating or a thorough shaking of a plant within the net will sometimes produce specimens which are utterly unobtainable by other means. They are so small and jump so quickly that an aspirator, while not indispensable, is of the greatest aid in their capture.

The adults may be preserved in alcohol or mounted dry on points or minuten nadeln. Mounting of the entire insect on slides after clearing and dismembering as practiced and recommended by Ferris and Klyver, who carried the idea over from the former's work with coccids, is not satisfactory. This is especially true where only one or two specimens are known. By this method one can ascertain many minutae, of course, such as the exact number and shape of setae or glands, but some of the more general and certainly more usable characters, such as proportionate length of various parts, shape of vertex and genal processes, angle of the latter with respect to the vertex, and color, are lost. It is often desirable



to clear and study some parts, such as the genitalia, under higher magnifications. When this is necessary a temporary glycerine mount of the cleared parts is preferable for study; after such study is completed, the part or parts are placed, still in a small drop of glycerine, in a minute vial, covered with refined mineral oil, corked, and placed with the untreated part of the insect by pinning through the cork. In this way the material is always available for further study, it may be viewed from any angle, further dissection may be made if desired and no distortion occurs such as is unavoidable in slide mounts. By the use of oil to cover and thus seal off the small drop of glycerine, any possibility of its creeping out and rusting the pin or ruining the label is forestalled.

Nymphs, on the other hand, are best preserved and studied as permanent slide mounts. As they are quite strongly flattened, almost no distortion occurs in such mounting nor are any characters obscured.

#### EXPLANATION OF TERMS AND METHODS

In order to prevent misunderstanding and confusion, the following explanations and definitions are given.

Only the over-all length from the tip of the head to the tip of the folded wings is given in millimeters. In making this measurement the insect is measured with a millimeter rule under a binocular microscope. This measuring is not done more accurately and no other such measurements are given for the reason that it has become evident from study of large series of specimens of various species that so much variation in size occurs within a species that exact measurements are of little significance. The proportions between various parts of the insect are in general quite constant, however, and have been utilized in lieu of metric fractions in the conviction that they are of much more value than the latter. The proportional measurements are made by means of a squared eyepiece in the ocular of the microscope.

The principal mensural terms are defined as follows:

*Width of head*—distance across head including eyes.

*Length of vertex*—total length from most caudal points to most anterior points, measured with vertex flat (not the median length).

*Width of vertex*—width between compound eyes.

*Length of genal processes*—length measured on median line from base of frons to apices of processes.

*Length of antennae*—total length including the two basal segments.

*Width of thorax*—width at widest point, as seen in dorsal view, usually across mesoscutum.

*Length of forewing*—total length measured parallel to straight portion of anal margin.

*Width of forewing*—greatest width at any point.

Wherever such comparative terms as long, short, large, etc., are used, they mean, of course, in proportion to the rest of the insect and imply comparison with the same structure in related species.

All descriptions are from dried specimens unless otherwise indicated.



The term *genal processes* has been substituted for *genal cones* as used by Crawford *et al.*, to obviate the absurdity of such expressions as, cones conical, cones transverse, etc.

The cell in the forewings between the branches of media is termed the *medial cell*, and that between the branches of cubitus, the *cubital cell*, for reasons of brevity and convenience. These names are much less confusing than the previously used *first marginal* and *second marginal*.

In those descriptions in which minute setae on the wing membrane are referred to, the tiny setae which were called points by Ferris *et al.* are meant, not the larger hairlike setae which occur quite commonly on the veins and occasionally on the membrane. These minute setae are often continuous with, but much smaller than those which make up the radular areas near the wing margin (the alar radulae of authors).

A group of individuals is considered as a *subspecies* when it shows some constant but minor morphological differences, usually coupled with a somewhat different range. Such probably represent incipient species.

*Variety* as herein used refers to a distinct, constantly reappearing variation in color or color pattern. Most of Crawford's varieties are based on morphological differences and are here classed as subspecies.

#### SYNONYMY AND BIBLIOGRAPHY

Under each species is listed the complete synonymy as known to the author. A complete list of references is included for most of the species. For those forms which are of considerable economic importance or for some other reason have received great attention, the list is necessarily curtailed and includes only those which are deemed pertinent to a work of this nature, that is, those which deal with the taxonomy, biology, or morphology of the species, or which contain a considerable bibliography of other types of papers. In these specific lists only abbreviated references are given. In the bibliography the complete title of the paper and of the publication is given.

The bibliography includes all works cited plus other important contributions with especial emphasis on those not included in Crawford's monograph.

Except where otherwise indicated, the original of all references has been seen.

#### ILLUSTRATIONS

An attempt has been made to include all such illustrations as are necessary for identification of species, but unnecessary repetition has been avoided as much as possible. Illustrations occurring in the literature which have been found satisfactory have been used in lieu of preparing new drawings. In choosing such illustrations, preference has been given to drawings published with the original description or those known to be of the type specimens. All such figures used have been checked against specimens wherever they have been available, and slight changes have

been incorporated in many. The author of each figure is given in the list of illustrations, those not otherwise credited are original.

#### LOCATION OF TYPES

Some of the insects in Fitch's collection, including the *Psyllidae*, found their way to the United States National Museum, and the types of his psyllid species are there. Van Duzee (Can. Ent. 44:317-329) discussed Provancher's collection, which he had studied, but he made no mention of the *Psyllidae*. It seems doubtful, therefore, that they have been preserved. Riley's types (where designated) are in the National Museum as are those of Ashmead and Schwarz. Mally's types, the location and existence of which have been problematical, are in the Iowa State College collection at Ames, Iowa. In reply to a query concerning the types of some of her species, Dr. Patch replied that the specimens "must be among those lent some time ago to someone who has not yet returned them." Whether this means that all of her types are thus lost I am unable to say. As the type specimens were not listed as such in many cases, no data concerning them have been available. Fortunately, photographs were published with her descriptions which make the identity of most of her species quite certain. Crawford's types are in the United States National Museum, and in his own collection, which has been recently added to the National Museum. The whereabouts of Klyver's types is unknown to the writer—presumably they are in his personal collection at San Mateo Junior College, San Mateo, California. Those of Van Duzee are in the Museum of the California Academy of Sciences. Caldwell reports that his types are in the Ohio State University collection. The European workers who have described species occurring in North America seem to have designated no types; at least no mention of them has been made in the literature.

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## SYSTEMATIC TREATMENT

### FAMILY PSYLLIDAE LATREILLE

- 1807 *Psyllidae* Latreille, Gen. Crust. Ins. 3:168.  
 1810 *Psyllidae* Latreille, Consid. Gen. sur L'Ordre Nat. Anim. 252, 264.  
 1814 *Chermides* Fallen, Spec. Nova. Hemip. Disp. Meth. Exhib. 3, 22.  
 1815 *Psyllides* Leach, Edinb. Encycl. 9:125 [*vide* Aulmann].  
 1825 *Psyllides* Latreille, Fam. Nat. Règne Anim. 428.  
 1835 *Psyllodes* Burmeister, Handb. d. Ent. 2:95.  
 1840 *Psylliens* Blanchard, Hist. des Ins., Hemip. 201.  
 1847 *Saltpedes* Amyot, Ann. Soc. Ent. Fr. 5 (2nd series):456.  
 1861 *Psyllodea* Flor, Rhyn. Livl. 2:438.  
 1861 *Psyllodea* Flor, Bull. Soc. Imp. Nat. Moscou 34:331.  
 1874 *Psyllodea* Lethierry, Cat. Hemip. du Nord. ed. 2:85 [*vide* Aulmann].  
 1876 *Psyllidae* Scott, Trans. Ent. Soc. London 1876:525-570.  
 1896 *Psyllina* Edwards, Hemip.-Homop. Br. Is.  
 1904 *Chermidae* Kirkaldy, Ent. 37:255.  
 1908 *Psyllidae* Oshanin, Verz. palae. Hemip. 2:338.  
 1912 *Psyllidae* Oshanin, Kat. paläa. Hemip. 125.  
 1913 *Psyllidae* Aulmann, Psy. Cat. 5.  
 1914 *Psyllidae* Crawford, U. S. Nat. Mus. Bull. 85.  
 1917 *Chermidae* Van Duzee, Cat. Hemip. N. Am. 782.  
 1935 *Psyllina* Haupt, Tierw. Mittel. 4, 3:221, 222.

Antennae filiform, usually of ten segments, sometimes fewer. Three ocelli, one medial on frons, two lateral near compound eyes near caudal edge of vertex. Genae often produced, variously shaped. Beak arising from posterior portion of head, usually enclosed by forecoxae, apparently arising between them. Thorax strongly developed for flying and jumping. Two pairs of wings, usually membranous, anterior pair sometimes thickened, coriaceous, veins of forewings consisting of radius (branched once), media (branched once), cubitus (branched once), first A (claval suture); venation of hind wings very variable, weak, often indicated merely by rows of setae, similar to forewing, radius and media usually unbranched. Usually all legs fitted for jumping; tarsi two-segmented. Metacoxa usually with large spur caudad. Male genital segment bearing a pair of somewhat elongate processes (forceps).

Type genus—*Psylla* Geoffroy.

Much confusion has arisen as to the correct family name for this group of insects since Kirkaldy (1904) proposed the name *Chermidae* for *Psyllidae* Latreille. Kirkaldy erroneously thought that Lamark (1801) designated *ficus* Linnaeus as the type of *Chermes*. Lamark, however, merely cited it as an example of the genus, and this is not acceptable as a type designation (Op. 79, Int. Comm. Zool. Nom.). Apparently because of this belief that *ficus* was the type of *Chermes*, Kirkaldy considered *Psylla* Geoffroy a synonym of *Chermes*. This left the *Psylla* of Latreille *et al.* without a name, as *ficus* is not congeneric with the species of the latter. He subsequently (1905) proposed *Psyllia* as a new name for this orphaned group. The family name would not have been *Chermidae* but *Psylliidae*, however, as the type of the family had been set as *Psylla* Latreille in 1807 by Latreille, the changing of the name of this genus

would merely have changed the root of the family name, not transferred it to another genus. Since the type of *Chermes* is *abietis* (an aphid) rather than *ficus*, Kirkaldy's contention is groundless.

E. P. Van Duzee, the chief proponent of the name *Chermidae*, while following Kirkaldy's names, based his argument on different grounds. In an editorial note in the Pan-Pacific Entomologist (7:96) he states his case quite clearly and in private communications states his views more completely. Briefly stated, his thesis is this: The *type* of any category *must* agree in all details with the published description. At first glance this position has a seemingly logical basis, and in the specific instance of *Chermes* versus *Psylla* his position appears sensible, but it is certainly not expedient, nor does it conform to the rules of nomenclature. To abandon the system of nomenclatorial rules established by the Zoölogical Congress and return to such a so called "logical" basis is of course unthinkable, and one shudders to think of the resulting confusion.

The name *Psyllidae* had been in general, almost exclusive, use for about 100 years when this "correction" first appeared, an instance in which, if it had been necessary, the International Commission would surely have suspended the rules to prevent confusion. It is unfortunate, indeed, that this needless confusion has existed and been so long continued.

#### KEY TO THE SUBFAMILIES (AFTER CRAWFORD)

1. Vertex deeply cleft medially, anteriorly (in *Rhinopsylla*, the only genus occurring in our fauna, media and cubitus of the forewing are not petiolate nor are the genae produced) . . . . . **Carsidarinae**<sup>1</sup>.  
Head not deeply cleft anteriorly . . . . . 2.
2. Frons covered by genae ventrally; genae usually produced as variously shaped processes . . . . . 3.  
Frons not covered by genae ventrally; genae not produced (except in *Calophya*) . . . 4.
3. Media and cubitus of forewing with a prominent common petiole; forewings rarely angulate apically; basal segment of metatarsus with two black spines at tip (lacking in *Tetragonocephala*) . . . . . **Psyllinae**.  
Media, cubitus, and radius of forewing arising from basal vein at same point (or very nearly so); forewings usually angulate apically; metatarsus without spines . . . . . **Triozinae**.
4. Vertex flat and horizontal . . . . . **Liviinae**<sup>1</sup>.  
Vertex smoothly rounded down anteriorly . . . . . **Pauropsyllinae**<sup>1</sup>.

<sup>1</sup> Occurring in North America but not within the scope of this work.

#### SUBFAMILY PSYLLINAE LÖW

- 1879 *Psyllinae* Löw, Verh. zool.-bot. Ges. Wien 28:605, 607.  
1886 *Psyllaria* Puton, Cat. Hém. Faune Paléa. 91.  
1896 *Psyllidae* Edwards, Hemip.-Homop. Br. Is. 227, 233.  
1908 *Psyllaria* Oshanin, Verz. palae. Hemip. 2:349.  
1912 *Psyllaria* Oshanin, Kat. palae. Hemip. 126.  
1913 *Psyllinae* Aulmann, Psy. Cat. 5.  
1914 *Psyllinae* Crawford, U. S. Nat. Mus. Bull 85:18, 105.  
1916 *Psyllinae* Van Duzee, Check List Hemip. N. Am. 87.  
1917 *Psyllinae* Van Duzee, Cat. Hemip. N. Am. 799.

Head more or less deflexed. Genae produced as variously shaped processes. Frons covered by genae except a small portion bearing median



ocellus. Antennae ten-segmented, length variable. Eyes hemispherical and lateral or somewhat elongate and recessive. Thorax variously arched. Forewings variable in shape and texture, media and cubitus with a common petiole, pterostigma commonly present but frequently obsolete. Metacoxal spurs present. Metatibiae often armed basally, a variable number of spines apically. Basal segment of metatarsus bearing two black clawlike spines except in *Tetragonocephala*. Male proctiger simple.

This is a very large and widely distributed subfamily, representatives being found throughout the world. There are few characters which can be cited as typical of it which will not show some exceptions. There is always a medial-cubital petiole in the forewing; the genae are produced as variously shaped processes which almost always cover the frons except for a small area which bears the median ocellus. Crawford considered the presence of the two black claws on the basal segment of the metatarsi as of great importance, which indeed it is, although these spines are lacking in one genus.

The nymphs are often quite active and free-living, others are gall-formers. Some are producers of copious quantities of wax; others seem to produce none. They characteristically have the wing pads extending prominently beyond the margin of the abdomen, not produced cephalad at the humeral angles, and are without a fringe of large setae on the margin.

TYPE: *Psylla* Geoffroy.

#### KEY TO THE GENERA OF *Psyllinae*

1. Head somewhat deflexed, not vertical. . . . . 2.  
Head very strongly deflexed, head and pronotum vertical. . . . . 7.
2. Genal processes large, flattened, contiguous, on same plane as vertex; forewings thickened, rugose, rhomboidal. . . . . *Euphyllura* p. 526.  
Genal processes not flattened, rarely contiguous; forewings usually membranous, sometimes thickened and rugose, not rhomboidal (except *Euphalerus propinquus*) . . . 3.
3. Pleural suture of prothorax extending to middle of lateral margin of pronotum, propleurites equal dorsally. . . . . 5.  
Pleural suture of prothorax oblique, propleurites not equal dorsally. . . . . 4.
4. Forewings broadly rounded apically . . . . . *Psylla* p. 455.  
Forewings strongly narrowed apically. . . . . *Spanioneura* p. 544.
5. Genal processes sharply depressed from plane of vertex, parallel to it. *Arytaina* p. 503.  
Genal processes not depressed from plane of vertex. . . . . 6.
6. Vertex flat, large; eyes recessive; genal processes somewhat porrect; forewings more or less thickened. . . . . *Euphalerus* p. 519.  
Vertex somewhat rounded to vertical genal processes; eyes lateral; forewings membranous. . . . . *Psyllopsis* p. 516.
7. Basal segment of metatarsus with two black claws. . . . . *Pachypsylla* p. 533.  
Basal segment of metatarsus without black claws. . . . . *Tetragonocephala* p. 542.

#### Genus *Psylla*\* Geoffroy

1758 *Chermes* Linne (*pro parte*), Syst. Nat. X:453-455.

1762 *Psylla* Geoffroy (?), Hist. Abr. ins. envir. Paris I:482-498 [*non viso, fide auct.*].

1764 *Psylla* Geoffroy, Hist. Abr. des Insectes 1:482, pl. X.

\* *Psylla* -ae, Gr. f. noun—a flea.



- 1804 *Psylla* Latreille, Hist. Nat. Crust. Ins. 3:266.  
 1810 *Psylla* Latreille, Consid. Gen. sur L'Ordre Nat. Anim. 434 [designates type].  
 1848 *Psylla* Förster, (*pro parte*), Verh. natur. Ver. preuss. Rheinl. 5:67.  
 1861 *Psylla* Flor (*pro parte*), Bull. Soc. Imp. Nat. Moscou 34:335, 337-377  
 1872 *Psylla* Meyer-Dür (*pro parte*), Mitt. Sch. Ent. Ges. 3:395.  
 1876 *Psylla* Scott (*pro parte*), Trans. Ent. Soc. London 1876:530.  
 1877 *Chermes* Thomson, Opusc. Ent. 8:820.  
 1879 *Psylla* Löw, Verh. zool.-bot. Ges. Wien. 28:600-603, 608.  
 1896 *Psylla* Edwards, Hemip.-Homop. Br. Is. 233-249.  
 1905 *Psyllia* Kirkaldy, Wien, Ent. Zeitg. 24:268.  
 1908 *Psylla* Oshanin, Verz. palae. Hemip. 2:350.  
 1912 *Psylla* Oshanin, Kat. palae. Hemip. 127.  
 1913 *Psylla* Aulmann, Psy. Cat. 8.  
 1914 *Psylla* Crawford, U. S. Nat. Mus. Bull. 85:135.  
 1914 *Brachypsylla* Crawford, (*pro parte*), U. S. Nat. Mus. Bull. 85:142.  
 1917 *Psyllia* Van Duzee, Cat. Hemip. N. Am. 805.  
 1918 *Labicria* Enderlein, Zool. Anz. 49:348.  
 1921 *Asphagis* Enderlein, Zool. Anz. 52:120.  
 1921 *Asphagidella* Enderlein, Zool. Anz. 52:120.  
 1926 *Baeopelma* Enderlein, Ent. Mitt. 15:399.  
 1935 *Psylla* Haupt, Tierw. Mittel, 4, 3:231, 232.  
 1938 *Psyllia* Caldwell, Ohio Biol. Surv. Bull. 34:260.

Head large, as broad as thorax or nearly so, deflexed. Vertex more or less depressed discally, shape somewhat variable. Genae produced as conical processes usually deflexed from plane of vertex. Eyes hemispherical. Antennae slender, usually longer than head, often much longer. Thorax large, well arched. Pronotum descending anteriorly, not flat. Propleurites not equal at juncture with pronotum, pleural suture oblique, extending to posterior edge of pronotum, or proepimeron not extending to pronotum at all. Forewings membranous, usually hyaline, transparent, rounded apically, cubitus and media with a common basal petiole, pterostigma present, obsolescent, or obsolete. Metatibiae usually with a large or small basal spur and five or six black spines apically. Basal segment of metatarsi with two black clawlike spines.

LOGOTYPE: *Psylla alni* (Linnaeus).

Linnaeus' genus *Chermes* (1758) contained fourteen species including *abietis* and *alni*. The first valid designation of a type species for *Chermes* is that of *abietis* by Passerini in 1863 (Arch. Zool. Anat. Fisiol. 2:205). As *abietis* is an aphid, *Chermes* is established as an aphid genus.

The first use of the name *Psylla* seems to have been in the 1762 edition of "Histoire abrégée des Insectes" which is generally accredited to Geoffroy. If the 1762 edition is not acceptable the name will date from 1764. Geoffroy's treatment is not binomial but is binary which is valid under the international code. Latreille first designated a type for the genus *Psylla* in 1810, naming *alni* Linnaeus.

Kirkaldy (1904) cited *Psylla* as a synonym of *Chermes*, basing this action on the ground that Lamark (1801) had designated *Chermes ficus* Linn. as the type of *Chermes* thereby making *Psylla* Geoffroy a synonym of *Chermes* and leaving *Psylla* Latreille without a name. For this latter group he proposed (1905) the name *Psyllia* Kirkaldy—type *Chermes pyri* Linn. As the type of *Chermes* is not *ficus* but *abietis*, an aphid, his action was groundless, and *Psyllia* is a synonym of *Psylla*.

Enderlein, in the later numbers of his "Psyllidologica," established a great many new genera, apparently without seeing any specimens of many of the species involved and using characters of slight significance. In this way he sometimes has placed very closely related species in different genera on some minor, scarcely specific character. *Labieria*, *Asphagis*, *Asphagidella*, and *Baeopelma* are four fragments which he thus splits from *Psylla* and which I do not believe to be worthy of generic distinction.

KEY TO THE SPECIES OF *Psylla*

1. Eyes borne on prominent stalklike portion of head . . . . . 55.
2. ( 1) Eyes not borne on prominent stalklike portion . . . . . 2.
2. ( 1) Antennae twice as long as width of head or longer . . . . . 3.
3. ( 2) Antennae distinctly less than twice as long as width of head . . . . . 21.
3. ( 2) Antennae more than  $2\frac{1}{2}$  times as long as width of head (usually 3 times as long) . . . . . 4.
4. ( 3) Antennae less than  $2\frac{1}{2}$  times as long as width of head . . . . . 10.
4. ( 3) Pterostigma present, prominent . . . . . 5.
5. ( 4) Pterostigma obsolete or almost obsolete . . . . . 7.
5. ( 4) Genal processes no longer than their basal width, typically rounded apically . . . . . *alni* p. 460.
6. ( 5) Genal processes longer than their basal width, sharper apically . . . . . 6.
6. ( 5) Female genital segment  $\frac{3}{4}$  as long as rest of body; male forceps enlarged apically . . . . . *caudata* p. 461.
7. ( 4) Female genital segment not over  $\frac{1}{2}$  as long as rest of body; male forceps nearly parallel margined to apices . . . . . *galeaformis* p. 462.
7. ( 4) Female genital segment longer than rest of abdomen, slender, styliform, abruptly enlarged basally; male forceps not notched apically . . . . . *floccosa* p. 463.
8. ( 7) Female genital segment shorter than rest of abdomen, stout; male forceps notched apically . . . . . 8.
8. ( 7) Uniformly green or greenish yellow in color . . . . . *trimaculata* var. *astigmata* p. 465.
9. ( 8) Not uniformly greenish, at least some red markings . . . . . 9.
9. ( 8) With three prominent red spots on dorsum of mesothorax, otherwise unicolorous . . . . . *trimaculata* p. 464.
10. ( 3) General color red, black bands on abdomen . . . . . *trimaculata* var. *cerasi* p. 465.
10. ( 3) Forewings with definite maculae . . . . . 11.
11. (10) Forewings without maculae . . . . . 12.
11. (10) Genal processes cone-shaped, as long as vertex . . . . . *maculata* p. 466.
12. (10) Genal processes small, blunt, less than  $\frac{1}{2}$  as long as vertex . . . . . *nana* p. 467.
12. (10) Male forceps simple\*, straight in lateral view (except *brevistigmata acuta*) . . . . . 13.
13. (12) Male forceps not simple and straight . . . . . 19.
13. (12) Female genital segment shorter than rest of abdomen . . . . . 14.
14. (13) Female genital segment longer than rest of abdomen . . . . . 16.
14. (13) Pterostigma large, long; genal processes large, blunt, scarcely divergent . . . . . *albigena* p. 468.
15. (14) Pterostigma broad but short; genal processes slender, subacute, strongly divergent . . . . . 15.
15. (14) Male forceps straight; vertex and genal processes striped red and white . . . . . *brevistigmata* p. 471.
- Male forceps bent sharply cephalad in apical  $\frac{1}{2}$ ; vertex and genal processes nearly unicolorous . . . . . *brevistigmata acuta* p. 472.

\* Simple as used in this key means tapered to an acute, subacute, or blunt apex, not broadly truncate, dentate, notched, lobate, emarginate, etc., the forceps may be curved or twisted, however.

16. (13) Female genital segment large basally, then attenuate, styliform. *floccosa* p. 463.  
Female genital segment stout, not styliform. . . . . 17.
17. (16) Apex of dorsal valve of female genital segment sharp. . . . . *carpinicola* p. 468.  
Apex of dorsal valve of female genital segment blunt. . . . . 18.
18. (17) Genal processes large, acute, fully as long as vertex. . . . . *dilonchi* p. 470.  
Genal processes small, blunt,  $\frac{1}{2}$  as long as vertex. . . . . *striata* p. 470.
19. (12) Female genital segment as long as rest of abdomen or longer; male forceps not cleft, bearing a large Y-shaped black tooth apically. . . . . *insignita* p. 473.  
Female genital segment shorter than abdomen; male forceps cleft. . . . . 20.
20. (19) Larger species (3.5 mm.); male forceps with only apical cleft, posterior lobe bearing an acute black tooth. . . . . *magna* p. 473.  
Smaller species (3 mm.); male forceps cleft nearly halfway to the base, caudo-mesal lobe ending in a T-shaped tooth. . . . . *omani* p. 474.
21. (2) Small species (2-2.5 mm.); genal processes separate basally, strongly divergent; forewings more or less fumate. . . . . 22.  
Larger species (2.5 mm. or more); genal processes not separate basally, less strongly divergent; forewings usually not fumate (more or less fumate in *alaskensis*, *pyricola* and *media*). . . . . 26.
22. (21) Head and thorax very prominently pubescent. . . . . *hirsuta* p. 474.  
Head and thorax not prominently pubescent. . . . . 23.
23. (22) Male forceps simple to apex. . . . . *minuta* p. 475.  
Male forceps not simple. . . . . 24.
24. (23) Male forceps deeply cleft apically. . . . . 25.  
Male forceps notched on lateral margin apically. . . . . *coryli* p. 476.
25. (24) Genal processes  $\frac{1}{2}$  as long as vertex; female genital segment  $\frac{1}{2}$  as long as rest of abdomen, dorsal valve sinuate, upturned apically. . . . . *media* p. 477.  
Genal processes  $\frac{1}{2}$  as long as vertex; female genital segment longer than rest of abdomen, valves straight, subequal. . . . . *difficilis* p. 477.
26. (21) Female genital segment distinctly longer than rest of abdomen, and male forceps simple. . . . . 27.  
Female genital segment at most as long as rest of abdomen, or if longer male forceps not simple. . . . . 32.
27. (26) Antennae  $1\frac{2}{3}$  times as long as width of head or more. . . . . 28.  
Antennae  $1\frac{1}{3}$  to  $1\frac{1}{2}$  times as long as width of head. . . . . 31.
28. (27) Apex of dorsal valve of female genital segment curved ventrad. *hartigii* p. 478.  
Apex of dorsal valve of female genital segment upcurved. . . . . 29.
29. (28) Dorsal valve of female genital segment with apex sharp. . . . . *stricklandi* p. 479.  
Dorsal valve of female genital segment with apex blunt. . . . . 30.
30. (29) Ventral valve of female genital segment nearly as long as dorsal valve, latter very abruptly upturned apically. . . . . *tuthilli* p. 480.  
Ventral valve of female genital segment distinctly shorter than dorsal valve, latter evenly upcurved. . . . . *magnicauda* p. 480.
31. (27) Large species (3.5 to 4 mm. to tip of folded wings). . . . . *buxi* p. 481.  
Smaller species (2.75 to 3 mm. to tip of folded wings). . . . . *bulbosa* p. 482.
32. (26) Antennae but slightly longer than width of head. . . . . 33.  
Antennae at least  $1\frac{1}{3}$  times as long as width of head (sometimes slightly less in *alaskensis*). . . . . 37.
33. (32) Male forceps T-shaped apically. . . . . *parallela* p. 492.  
Male forceps not T-shaped. . . . . 34.
34. (33) Forewings more or less fumate; male forceps with broad platelike caudal lobe. . . . . *manisi* p. 483.  
Forewings not fumate (often whitish); male forceps without platelike caudal lobe. . . . . 35.
35. (34) Uniformly yellowish green in color; head and thorax not punctate; genal processes  $\frac{3}{4}$  as long as vertex. . . . . *breviata* p. 484.  
General color red to reddish brown, more or less marked with black and white; genal processes  $\frac{1}{2}$  or  $\frac{2}{3}$  as long as vertex. . . . . 36.

36. (35) Female genital segment elongate, slender, dorsal valve straight; male forceps in lateral view swollen midway, tapered to apices, curved caudad, apices truncate with a small sharp anterior tooth. . . . *quadrilineata* p. 484.  
 Female genital segment short, dorsal valve concave; male forceps in lateral view very broad, apically twisted caudad, apices broadly rounded teeth. . . . *confusa* p. 492.
37. (32) Male forceps simple, blunt to acute apically (not truncate). . . . 38.  
 Male forceps not simple. . . . 43.
38. (37) Genal processes almost as long as vertex; light green species. . . . 39.  
 Genal processes not over  $\frac{2}{3}$  as long as vertex; dark-colored species. . . . 40.
39. (38) Length to tip of folded wings 4 mm.; genal processes slender, divergent; female genital segment much shorter than rest of abdomen, valves nearly equal. . . . *mali* p. 485.  
 Length to tip of folded wings 3 mm.; genal processes stout, nearly contiguous; female genital segment nearly as long as rest of abdomen *alba* p. 487.
40. (38) Forewings with a black spot at apex of clavus, often somewhat fumate. . . . 41.  
 Forewings immaculate. . . . 42.
41. (40) Genal processes uniformly white, robust; pterostigma narrow. . . . *ribesiae* p. 487.  
 Genal processes dark, at least basally, less robust; pterostigma large *pyricola* p. 489.
42. (40) Proctiger distinctly longer than forceps. . . . *americana* p. 490.  
 Proctiger scarcely longer than forceps, usually enclosing latter apically *americana curta* p. 491.
43. (37) Forewings with a prominent dark spot at apex of clavus. . . . *ribesiae* p. 487.  
 Forewings immaculate (except pterostigma may be dark; more or less fumate in *alaskensis* and *media*). . . . 44.
44. (43) Male forceps narrowed before apex then enlarged and truncate, somewhat T-shaped in appearance. . . . 45.  
 Male forceps not T-shaped. . . . 47.
45. (44) Length to tip of folded wings 3 mm. . . . *parallela* p. 492.  
 Length to tip of folded wings 3.5 to 4 mm. . . . 46.
46. (45) General color dark brown to black. . . . *minor* p. 493.  
 General color yellow. . . . *minor* var. *flava* p. 494.
47. (44) Male forceps deeply notched apically. . . . 48.  
 Male forceps otherwise. . . . 49.
48. (47) Forewings fumate; pterostigma very small. . . . *media* p. 477.  
 Forewings clear; pterostigma moderately large. . . . *usitata* p. 494.
49. (47) Male forceps broad, apices very broadly truncate and heavily sclerotized *latiforceps* p. 495.  
 Male forceps otherwise. . . . 50.
50. (49) Male forceps very broad, flattened, narrowed toward apices, twisted caudad, apices visible only in caudal view, sharply narrowed near tips, terminating as a blunt rounded tooth, somewhat sinuate on caudal margin *confusa* p. 492.  
 Male forceps otherwise. . . . 51.
51. (50) Male forceps strongly sinuate on caudal margin. . . . *sinuata* p. 496.  
 Male forceps otherwise. . . . 52.
52. (51) Male forceps produced as rounded lobes basally on caudal margin *fibulata* p. 497.  
 Male forceps otherwise. . . . 53.
53. (52) Proctiger of male about as long as forceps; forceps hooked cephalad apically. . . . 54.  
 Proctiger of male very long, twice as long as forceps; forceps bent caudad apically, truncate. . . . *propria* p. 497.
54. (53) Entire apical portion of forceps hooked cephalad, visible in lateral view. . . . *uncata* p. 498.

- Forceps bearing a small apical hook, scarcely visible in lateral view; forewings typically much narrowed and elongate. . . . . *alaskensis* p. 499.
55. ( 1) Forewings twice as long as wide. . . . . *phoradendri* p. 500.
- Forewings  $2\frac{1}{2}$  times as long as wide. . . . . 56.
56. (55) Antennae annulated with black. . . . . *annulata* p. 501.
- Antennae unicolorous except tip dark. . . . . *negundinis* p. 501.

*Psylla alni*\* (Linnaeus)

(Figs. 1, 2, 7, 8, 255)

- 1758 *Chermes alni* Linnaeus, Syst. Nat. X:454.
- 1761 *Chermes alni* Linnaeus, Fauna Svecica 263.
- 1773 *Psylla alni* Linnaeus, DeGeer Mem. I, III:148 [*fide* Aulmann].
- 1841 *Psylla alni* Hartig, Germ. Zeitschr. Ent. 3:373.
- 1848 *Psylla alni* Förster, Verh. natur. Ver. preuss. Rhein. 5:70.
- 1848 *Psylla fuscinervis* Förster, *ibid.* 5:70.
- 1848 *Psylla heydeni* Förster, *ibid.* 5:81.
- 1861 *Psylla alni* Flor, Rhynch. Liv. 2:460.
- 1861 *Psylla alni* Flor, Bull. Soc. Imp. Nat. Moscow 34: 342, 350, 353.
- 1869 *Chermes alni* Thomson, Opusc. Ent. 8:831.
- 1872 *Psylla alni* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:395.
- 1872 *Psylla fuscinervis* Meyer-Dür, *ibid.* 395.
- 1872 *Psylla heydentii* Meyer-Dür, *ibid.* 395.
- 1876 *Psylla alni* Scott, Trans. Ent. Soc. London 1876:532.
- 1896 *Psylla alni* Edwards, Hemip.-Homop. Br. Is. 248.
- 1907 *Psylla alni* Kuwayama, Trans. Sap. Nat. Hist. Soc. 2:169.
- 1908 *Psylla alni* Oshanin, Verz. palae. Hemip. 2:356.
- 1913 *Psylla alni* Aulmann, Psy. Cat. 9.
- 1914 *Psylla alni americana* Crawford, U. S. Nat. Mus. Bull. 85:139, 156.
- 1914 *Psylla alni gossypiona* Crawford, U. S. Nat. Mus. Bull. 85:157.
- 1917 *Psylla alni americana* Van Duzee, Cat. Hemip. N. Am. 811.
- 1932 *Psylla alni americana* Klyver, Pan-Pac. Ent. 8:17.
- 1932 *Psylla alni americana* Klyver, Ent. News 43:74.
- 1938 *Psylla alni americana* Strickland, Can. Ent. 70:204.
- 1939 *Psylla alni americanella* Strickland, Can. Ent. 71:214.

Length to tip of folded wings 4.5 to 5 mm.

COLOR: General color yellowish green. Antennae dark in distal half. Forewings clear, veins often bright green.

STRUCTURE: Head broad, strongly deflexed. Eyes unusually large. Vertex  $\frac{1}{2}$  as long as wide, two discal foveae, clothed with very short, sparse pubescence. Genal processes short,  $\frac{2}{3}$  as long as vertex, divergent, from blunt to subacute. Antennae about 3 times as long as width of head. Thorax well arched. Pronotum long, half as long as prescutum. Hind tibia with small basal spur. Forewings with typical venation,  $2\frac{2}{3}$  times as long as wide, pterostigma small.

GENITALIA: Male proctiger long, straight to near apex then hooked caudad. Forceps in lateral view slender basally, enlarged apically; in caudal view slightly but evenly arched; apex truncate, black-margined, often somewhat excavate thus appearing slightly bidentate. Female genital segment longer than rest of abdomen, prominently pubescent, slightly upcurved, broad basally, evenly narrowed to apex; dorsal valve longer than ventral, styliform in apical third, blunt; ventral valve very slender apically.

\* Genitive of *Alnus*—the generic name of the host plants.



In the tenth edition of *Systema Naturae*, Linnaeus gives North America as the habitat of *alni*. The designation of American specimens as a subspecies is therefore an error. I have examined European specimens (Austria) and find them to be identical with North American material.

As the name indicates the host is *Alnus* (alder), of several species. Strickland records it as occurring on "*Betulosa glandulosa*" (apparently *Betula*) in Alberta. Numerous specimens are at hand from various localities in California and Oregon; Oak Creek Canyon, Arizona; and Asotin, Washington. It has also been recorded from Nevada, British Columbia, Idaho, and Alberta. Outside North America it has been reported from almost all of Europe, from Russia, and from Japan.

*Psylla caudata*\* Crawford

(Figs. 9, 10)

1914 *Psylla caudata* Crawford, U. S. Nat. Mus. Bull. 85:139, 157.

1917 *Psyllia caudata* Van Duzee, Cat. Hemip. N. Am. 811.

1932 *Psyllia caudata* Klyver, Pan-Pac. Ent. 8:17.

1932 *Psyllia caudata* Klyver, Ent. News 43:75.

Length to tip of folded wings 4.5 to 5 mm.

COLOR: General color light to dark brown in fully matured specimens. Younger individuals greenish yellow. Antennae dark from third segment.

STRUCTURE: Head rather small, strongly deflexed. Vertex strongly impressed discally,  $\frac{1}{2}$  as long as wide. Genal processes rather short, cone-shaped, blunt, about  $\frac{2}{3}$  as long as vertex, as long as vertex on median line. Antennae slightly over  $2\frac{1}{2}$  times as long as width of head. Thorax somewhat arched. Pronotum large. Hind tibia with prominent basal spur. Forewings large, often milky, membrane very thickly set with small setae,  $2\frac{1}{2}$  times as long as wide; medial cell large, pterostigma prominent. Hind wings very long, equalling genital segment in female.

GENITALIA: Male proctiger short, straight. Forceps in lateral view slightly curved cephalad, slender basally, much enlarged apically; apices black, notched; in caudal view slender, slightly arched. Female genital segment extremely long, upcurved, about  $\frac{3}{4}$  as long as rest of body (often appearing even longer due to the partially exerted ovipositor); ventral valve slender, attenuate, acute apically; dorsal valve much longer than ventral, very slender and styliform in apical half, apex scarcely acute; an apparent suture across segment midway.

Described from several hundred specimens from Colorado taken on alder (*Alnus* sp.). This species is similar to *galeaformis* in many respects but can readily be separated from the latter by the color, which is typically much darker, the smaller genal processes, and the genitalia of both sexes. Both the forceps and proctiger of the male are much shorter than they are in *galeaformis*, and the forceps are much enlarged apically. The

\* *caudatus* -a -um, L. adj.—tailed.



extremely long and upcurved female genital segment is instantly recognizable.

Klyver has recorded it from Vancouver, British Columbia, and Idaho. These are the only records of its occurrence outside of Colorado where I have taken it in great numbers in company with *P. floccosa*.

TYPE, male, Pagosa Springs, Colorado, Baker, in Crawford Collection.

*Psylla galeaformis*\* Patch

(Figs. 11, 12)

1911 *Psylla galeaformis* Patch, Me. Agr. Exp. Sta., Bull. 187:12-14.

1914 *Psylla galeaformis* Crawford, U. S. Nat. Mus. Bull. 85:157.

1917 *Psylla galeaformis* Van Duzee, Cat. Hemip. N. Am. 812.

1923 *Psylla galeaformis* Patch, Hemip. Conn. 249.

Length to tip of folded wings 4.5 to 5 mm.

COLOR: General color green to yellow to reddish brown. Antennae dark distally. Wings hyaline to yellowish.

STRUCTURE: Head strongly deflexed. Vertex with deep discal impressions,  $\frac{1}{2}$  as long as wide. Genal processes large, cone-shaped, straight, blunt, as long as vertex. Antennae slightly less than 3 times as long as width of head. Thorax well arched. Pronotum large, strongly descending. Hind tibia with large basal spur. Forewings typical in size and venation, pterostigma small. Membrane of both fore and hind wings set with minute setae. Hind wings large, exceeding abdomen.

GENITALIA: Male proctiger long, straight, slender. Forceps slender; in lateral view slightly curved cephalad, almost parallel-margined to apices; apices black, notched; in caudal view narrow, strongly arched. Female genital segment longer than rest of abdomen, slender, with prominent pubescence; ventral valve very slender and attenuate in apical half, acute; dorsal valve longer than ventral, apical third very slender, straight, apex blunt with a rosette of short stiff setae.

Described from a large series of specimens from Dixfield, Maine, August 20, 1934, P. W. Oman. Specimens are also at hand from the following states and provinces: Vermont, Massachusetts, New Hampshire, Nova Scotia, Ontario, Michigan, Wisconsin, Minnesota, Manitoba, Saskatchewan, Colorado, Utah, Nevada, Oregon, Washington, and British Columbia. The host is alder (*Alnus*), apparently of several species (*A. incana* and *A. tenuifolia*). It has also been recorded from New York and Connecticut.

As Crawford indicates, this may be identical with *Diraphia viridescens* (= *4-cornis*) Provancher. Without seeing Provancher's specimens this cannot be determined, however.

\* From *galea* -ae, L. f. noun—helmet + *formis* (comb. form of *forma* -ae, L. f. noun) — shape.

*Psylla floccosa*\* Patch

(Figs. 13, 14)

- 1909 *Psylla floccosa* Patch, Ann. Ent. Soc. Am. 2:117 [*nomen nudum*].  
 1909 *Psylla floccosa* Patch, Can. Ent. 41:301-303.  
 1911 *Psylla floccosa* Patch, Me. Agr. Exp. Sta., Bull. 187:11-12.  
 1913 *Psylla floccosa* Aulmann, Psy. Cat. 15.  
 1914 *Psylla floccosa* Crawford, U. S. Nat. Mus. Bull. 85:154.  
 1914 *Psylla styliformis* Crawford, U. S. Nat. Mus. Bull. 85:154.  
 1917 *Psyllia floccosa* Van Duzee, Cat. Hemip. N. Am. 810.  
 1921 *Asphagidella floccosa* Enderlein, Zool. Anz. 52:120.  
 1922 *Psyllia floccosa* Osborn, N. Y. St. Coll. For., Tech. Pub. 16:54.  
 1923 *Psylla floccosa* Patch, Hemip. Conn. 249.  
 1932 *Psyllia floccosa* Klyver, Ent. News 43:73.  
 1938 *Psyllia floccosa* Strickland, Can. Ent. 70:204.  
 1939 *Psyllia floccosa* Strickland, Can. Ent. 71:215.

Length to tip of folded wings 5 to 5.5 mm.

**COLOR:** Green to greenish yellow, sometimes brownish dorsally. Antennal segments with dark annuli, distal segments entirely dark. Wings clear.

**STRUCTURE:** Head scarcely as long as thorax, strongly deflexed. Vertex about  $\frac{1}{2}$  as long as wide, discal impressions shallow, anterior margin not abrupt or overhanging median ocellus. Genal processes large, cone-shaped, blunt, slightly longer than vertex. Antennae typically over 3 times as long as width of head (numerous Colorado, Utah, and Oregon specimens at hand have the antennae slightly less than  $2\frac{1}{2}$  times as long as width of head). Thorax well arched. Pronotum large. Hind tibia with small basal spurs. Forewings large, slightly less than  $1\frac{1}{2}$  times as long as wide; membrane set with minute setae; venation typical, pterostigma almost or entirely lacking.

**GENITALIA:** Male proctiger long, straight. Forceps much shorter than proctiger; in lateral view straight; in caudal view slender, evenly arched to apices; apices slightly pointed, black. Female genital segment longer than rest of abdomen, large basally, very suddenly narrowed, styliform to apex; ventral valve acute; dorsal valve slightly longer than ventral, more slender, straight, apex upturned as a small dorsal tooth.

Described from many specimens from the following states and provinces: Nova Scotia, New Hampshire, Maryland, Ontario, Michigan, Minnesota, Manitoba, Montana, Wyoming, Colorado, New Mexico, Utah, Nevada, California, Oregon, Washington, and British Columbia.

It has also been recorded from Maine, Connecticut, New York, and Alberta.

The nymphs are very conspicuous on the host, alder (*Alnus* spp.), being covered with a very abundant flocculent waxy secretion. The wax is easily removed, leaving the nymphs naked. Miss Patch has recorded the life history briefly: "The eggs are probably deposited upon the alder in the fall, as the newly-hatched Psyllids appear about the time the alder leaves are unfolding in the spring, and settle upon the ventral surface of

\* *floccosus* -a -um, L. adj.—woolly.

the leaves. . . . The mature winged forms are present in great numbers on the ventral sides of the leaves, freshly emerged and not yet taken to flight (June 6)." Near Creede, Colorado (elevation 9,000 ft.), the adults appear about the first of June. The Colorado specimens and others from the western area have much shorter antennae than the typical form as noted in the description. Specimens from the San Jacinto Mountains of California have the longest antennae of any of the numerous specimens at hand.

Specimens of Crawford's *P. styliformis* are in the United States National Museum.

*Psylla trimaculata*\* Crawford

(Figs. 15, 16)

1911 *Psylla alni trimaculata* Crawford, Pom. Coll. Jour. Ent. 3:631.

1914 *Psylla trimaculata* Crawford, U. S. Nat. Mus. Bull. 85:155.

1917 *Psyllia trimaculata* Van Duzee, Cat. Hemip. N. Am. 810.

1922 *Psyllia trimaculata* Osborn, N. Y. St. Coll. For., Tech. Pub. 16:54, 101-104 [life history notes].

1932 *Psyllia trimaculata* Klyver, Ent. News 43:74.

Length to tip of folded wings 5 mm.

COLOR: General color yellow or greenish yellow. A large median spot on anterior portion of prescutum, a large spot on each side of scutum, red. Antennae dark except three basal segments. Forewings hyaline. Hind wings slightly whitish.

STRUCTURE: Head small, narrow. Vertex twice as wide as long, deeply excavate between lateral ocelli. Genal processes as long as vertex, scarcely divergent, slender apically, blunt. Antennae pubescent, 3 times as long as width of head. Thorax well arched. Pronotum large, roundly produced cephalad mesally. Hind tibia with large basal spur. Forewings large,  $1\frac{1}{3}$  to  $1\frac{1}{2}$  times as long as body, very broadly rounded; veins biserially set with small setae; membrane with numerous extremely small setae; medial cell unusually large, elongate, petiole of cubitus and media very short, pterostigma very narrow, almost obsolete. Hind wings very long, greatly exceeding abdomen.

GENITALIA: Male proctiger stout, slightly produced on caudal margin. Forceps short; in lateral view slender, enlarged apically; in caudal view heavy, strongly arched to black apices; in dorsal view apices notched to form two acute black teeth, cephalic tooth larger than caudal, somewhat variable. Female genital segment shorter than rest of abdomen; dorsal valve straight to blunt black apex, apical portion slender; ventral valve upcurved in apical half to meet dorsal, acute; long silky pubescence on both valves.

Described from numerous specimens from New York, New Hampshire, Michigan, Wisconsin, Minnesota, Manitoba, and Florida. This species is apparently numerous wherever its hosts (various species of

\* From *tri* L. — three + *maculatus*, L. (p. part. of *maculare*)—spotted.

*Prunus*, wild cherry) occur. Numerous specimens collected in Minnesota show gradations from typical trimaculate forms to unmarked individuals. The latter are identical with *P. astigmata* Crawford, which name is retained as a variety, however, since typical specimens of the two forms are so distinct in appearance. Osborn (1922) noted the same facts and made *astigmata* a direct synonym of *trimaculata*. Strickland (Can. Ent. LXXI:215, 1939) has taken both males and females of a darker form, apparently that described as *P. cerasi* Patch from the female only, and concludes that they are only a color variant of *astigmata*. It is interesting to note that both Miss Patch's and Strickland's specimens were taken in September and in quite northerly latitudes. It seems probable that a temperature factor is responsible for the greater pigmentation. Miss Patch notes (1923) that her *P. cerasi* is "pale early in the season but richly colored in fall."

Crawford (1914 l.c.) says of the three forms involved: "It is possible that all three will prove to be but variations of one species."

TYPE, female, Gowanda, New York, August 2 to 9, 1907, Van Duzee, in the Crawford Collection.

*Psylla trimaculata* var. *astigmata*\* Crawford n. comb.

1914 *Psylla astigmata* Crawford, U. S. Nat. Mus., Bull. 85:139, 155.

1917 *Psyllia astigmata* Van Duzee, Cat. Hemip. N. Am. 810.

1921 *Asphagidella astigmata* Enderlein, Zool. Anz. 52:120.

1932 *Psyllia astigmata* Klyver, Pan-Pac. Ent. 8:16.

1932 *Psyllia astigmata* Klyver, Ent. News 43:74.

1939 *Psyllia cerasi astigmata* Strickland, Can. Ent. 71:215.

Identical with the typical form except in color. The three red maculae on the mesothorax lacking. Green to yellow unicolorous. Numerous specimens are at hand from Wisconsin, Michigan, Minnesota, Colorado, Arizona, Idaho, California, Oregon, Washington, and British Columbia. Many of the western specimens have genal processes which are proportionately shorter and thicker than is typical. It is also recorded from Nova Scotia and Alberta.

TYPE, female, Polk Co., Wisconsin, July, Baker, in Crawford Collection.

HOST: *Prunus* spp.

*Psylla trimaculata* var. *cerasi*† Patch n. comb.

1912 *Psylla cerasi* Patch, Me. Agr. Exp. Sta., Bull. 202:223.

1914 *Psylla cerasi* Crawford, U. S. Nat. Mus., Bull. 85:156.

1917 *Psyllia cerasi* Van Duzee, Cat. Hemip. N. Am. 810.

1923 *Psylla cerasi* Patch, Hemip. Conn. 249.

1939 *Psyllia cerasi* Strickland, Can. Ent. 71:215.

Distinguished from typical *trimaculata* by the color of the females. Patch describes the color as follows: "dorsal head and thorax rosy, dorsal

\* From *a*, Gr. — without + *stigma* -atis, L. f. noun — mark.

† Genitive of *cerasus* -i, L. f. noun—cherry tree.

abdomen almost vermillion, a black spot on dorsum of 1st abdominal segment, five vivid black transverse bands across the abdominal dorsum, the last coming just cephalad the genital segment. Antennal joints I, II, III rosy, rest black. Eyes bright black and bulging to width of thorax or slightly more. Wings clear and a little brownish. Ventral body pale."

Strickland collected numerous males and females of this form in Alberta. He found the males to be much less highly pigmented than the females, in fact he states that many of the males were indistinguishable from *astigmata*.

Apparently Miss Patch's and Strickland's specimens are the only known collections of this color variety. One teneral female in the United States National Museum bears no locality label.

This is probably Provancher's *Diraphia sanguinea* (as Crawford suggests), but without a study of his types this cannot be determined.

### *Psylla maculata*\* Crawford

(Figs. 17, 52, 52a)

1914 *Psylla maculata* Crawford, U. S. Nat. Mus., Bull. 85:137, 141.

1917 *Psyllia maculata* Van Duzee, Cat. Hemip. N. Am. 806.

1925 *Psylla maculata* Crawford, Proc. Haw. Ent. Soc. 6:31 [male described].

Length to tip of folded wings 2.50 to 2.75 mm.

COLOR: General color dark brown. Vertex, posterior half of pronotum, posterior portion of prescutum, longitudinal bands on scutum, scutellum, genal processes, distal portions of legs, margins of abdominal sclerites, lighter brown to yellow. Forewings with brown maculae along cubitus and media, including most of medial cell and extending to Rs at margin.

STRUCTURE: Vertex almost twice as wide as long, pubescent on anterior margin, discal foveae very prominent. Genal processes as long as vertex, cone-shaped, separated at base. Antennae slightly over twice as long as width of head. Thorax typical. Basal spur on hind tibia small. Forewings somewhat less than  $2\frac{1}{2}$  times as long as wide; veins setaceous; pterostigma short and wide, Rs sinuate.

GENITALIA: Male proctiger rather short, in lateral view narrow, curved caudad. Forceps bearing a very large acute retrorse hook on caudal margins reaching almost to base, apices acute, black. Female genital segment shorter than rest of abdomen, both valves acute, dorsal longer than ventral, excavate dorsally.

Described from numerous specimens collected at Mesa Verde, Colorado, on *Cercocarpus parvifolius*. Also at hand are specimens from Durango and Poudre River Canyon, Colorado. The males have very distinctive forceps, the large retrorse hooks on them being quite unlike anything known in the genus. The male from California described by Crawford is apparently a different species as he certainly would not

\* *maculatus*, L. (p. part. of *maculare*)—spotted.



have overlooked such a prominent structure. A male of the series at hand (Mesa Verde, Colorado, July 18, 1938, L. D. Tuthill) is therefore designated as the allotype and deposited in the United States National Museum.

TYPE, female, No. 18107 United States National Museum, Colorado, Baker.

Type examined.

HOST: *Cercocarpus parvifolius*.

*Psylla nana*\* Tuthill

(Figs. 53, 54, 277)

1938 *Psylla nana* Tuthill, Ent. News 49:242.

Length to tip of folded wings 2 to 2.55 mm.

COLOR: General body color, including legs, dirty white, with orange markings. Vertex white with margins, median line and discal foveae orange; genal processes white; antennal segments dark on apices, last two segments black. Thoracic dorsum with a median orange line, a pair of broader orange stripes on each side of scutum. Forewings more or less fumate in basal half; membrane whitish with somewhat irregular brown maculae as illustrated; veins white.

STRUCTURE: Head of medium size. Vertex bulging forward between antennae, medial suture and discal impressions prominent. Genal processes small, blunt, somewhat pubescent, slightly over  $\frac{1}{2}$  as long as vertex. Antennae about twice as long as width of head. Thorax relatively flat. Hind tibia with large basal spur. Forewings  $2\frac{1}{3}$  times as long as wide, broadly rounded; venation typical, medial cell larger than cubital, pterostigma very short.

GENITALIA: Male genitalia quite large. Proctiger slightly longer than forceps, tapering from rather broad base, apex bent caudad at right angles. Forceps fairly broad in lateral view, curved cephalad and then caudad near apices, apices black; in caudal view almost straight. Female genital segment shorter than rest of abdomen; dorsal valve straight on dorsal side; ventral valve evenly curved up to apex, slightly exceeded by dorsal valve.

Known from several points in Arizona. (Santa Rita Mountains, Chiricahua Mountains, Patagonia).

Host unknown.

TYPE, male, Santa Rita Mountains, Arizona, in Snow Collection, University of Kansas.

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\* *nana* -ae, L. f. noun—dwarf.



*Psylla albagena*\* (Caldwell)

(Figs. 18, 19)

1938 *Psyllia albagena* Caldwell, Ohio Biol. Surv., Bull. 34:261, 262-264.

Caldwell's description of this species is as follows:

"Length to tip of forewing 2.5-3.5 mm.; forewing 2-2.3 mm.

"Color: Genal cones light gray to white; vertex light orange to yellow; pronotum dark gray; prescutum and scutum orange; abdomen green; legs sooty white; forewings appearing white; sometimes whole body covered with a white dust.

"Head over twice as broad as long. Vertex almost two-thirds as long as broad; dorsal margin concave; depressed discally. Genal cones as long as vertex at median line, divergent; apices not broadly rounded; bases moderately depressed below plane of vertex.

"Thorax strongly arched; pronotum and prescutum strongly descending. Forewing almost two and one-half times as long as broad, hyaline; pterostigma rather broad and long.

"Genitalia: Male genital plate small. Forceps short, moderately stout. Proctiger one and one-half times longer than forceps. Oedeagus swollen and hooked apically.

"Female genital segment shorter than rest of abdomen. Dorsum of dorsal valve sinuate; apical fourth straight, narrow; apex broadly rounded. Ventral valve short, stout."

I have a pair of paratypes of this willow-inhabiting species. Some additional data taken from them are: Genal processes very large, blunt. Antennae twice as long as width of head. Thorax scarcely arched. Hind tibia with small basal tubercle. Male proctiger slightly flexed caudad. Forceps simple, straight, slightly turned cephalad apically.

Caldwell also describes the various stadii nymphs and gives some biological data.

Host *Salix longifolia*.

TYPE, male, in Ohio Biological Survey Collection, Ohio State University.

*Psylla carpinicola*† Crawford

(Figs. 20, 21)

1851 *Psylla carpini* Fitch, 4th Rept. N. Y. St. Mus., 64.[non] *Psylla carpini* Förster, Verh. natur. Ver. preuss. Rhein. 5:72. 1848.1885 *Psylla carpini* Riley, Proc. Biol. Soc. Wash. 2:69.1910 *Psylla carpina* Smith, Ins. N. J. 109.1913 *Psylla carpini* Aulmann, Psy. Cat. 12.1914 *Psylla carpinicola* Crawford, U. S. Nat. Mus., Bull. 85:151.1914 *Psylla cephalica* Crawford, U. S. Nat. Mus., Bull. 85:138, 151.1917 *Psyllia carpinicola* Van Duzee, Cat. Hemip. N. Am. 809.1917 *Psyllia cephalica* Van Duzee, Cat. Hemip. N. Am. 809.1918 *Psylla carpinicola* McAtee, Ent. News 29:224.

\* From *albus* -a -um, L. adj. - white + *gena* -ae, L. f. noun—cheek (*gena* of insect).

† From *Carpinus* the generic name of the host + *cola*, L.—inhabitant.

1918 *Psylla cephalica* McAtee, Ent. News 29:224.

1922 *Psyllia carpinicola* Osborn, N. Y. St. Coll. For., Tech. Pub. 16:54.

1938 *Psyllia carpinicola* Caldwell, Ohio Biol. Surv., Bull. 34:266.

Length to tip of folded wings 4 mm.

COLOR: Variable in color from uniform light green to reddish brown. Forewings clear to slightly fumate, veins green.

STRUCTURE: Head large, strongly deflexed (typically). Vertex slightly over  $\frac{1}{2}$  as long as broad, discal impressions slight, genal processes large, blunt, pubescent, variable in angle, in shape, in length, usually about  $\frac{3}{4}$  as long as vertex. Antennae twice as long as width of head (Crawford and Caldwell both record the antennae as  $2\frac{1}{2}$  times as long as width of head, but I have been unable to find any of more than very slightly over twice the head width). Thorax scarcely arched. Hind tibia with large spur at base. Forewings somewhat rugose; membrane evenly set with numerous very small setae,  $2\frac{1}{2}$  times as long as wide; veins biserially setate, venation variable in curvature of Rs and amount of arching in  $Cu_1$ , pterostigma small, also somewhat variable.

GENITALIA: Male proctiger slender, narrowed, and bent caudad in apical third. Forceps shorter than proctiger; in lateral view stout, straight, slightly enlarged apically; in caudal view very slender, gently arched to apices, terminating in a small black tooth. Female genital segment large, longer than rest of abdomen; dorsal valve much longer than ventral, dorsal margin sinuate, apical third attenuate, apex upcurved, acute; ventral valve acute, upcurved.

At hand are specimens from New York, Connecticut, New Hampshire, Nova Scotia, Pennsylvania, New Jersey, Maryland, District of Columbia, Virginia, North Carolina, Alabama, Florida, Mississippi, Louisiana, Missouri, Illinois, Ohio, Michigan, Wisconsin, Iowa, and Kansas. Crawford (1914) records specimens from Nevada; these, however, are *dilonchi* which he had not separated from *carpinicola*. His confusion of these two forms accounts for some of the indefiniteness of his description.

*P. cephalica* was established on the greater arch in vein  $Cu_1$  and several other minor variations from the type which are apparently of no specific significance. Typical examples of *cephalica* are abundant from Mississippi, Alabama, and Florida. Specimens from more northern localities show a gradual decrease in the amount of variation from the type, which is a specimen from New York.

The host of this very abundant species is *Carpinus caroliniana*.

Fitch's type series is in the United States National Museum.

TYPE, No. 1343 United States National Museum (Fitch's No. 9680).

Type examined.

*Psylla dilonchi*\* (Caldwell)

(Figs. 22, 23)

1914 *Psylla coryli* Crawford, U. S. Nat. Mus., Bull. 85:150.[non] *Psylla coryli* Patch, Me. Agr. Exp. Sta., Bull. 202:223. 1912.1938 *Psyllia diloncha* Caldwell, Ohio Biol. Surv., Bull. 34:261, 267.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: Pale green to yellow. Apical half of antennae with segments annulated, tip black. Forewings slightly yellowish.

STRUCTURE: Head only slightly deflexed. Vertex  $\frac{1}{2}$  as long as wide, discal impressions slight, scarcely emarginate anteriorly. Genal processes large, cone-shaped, acute, extending forward and almost on same plane as vertex, with long silky pubescence, fully as long as vertex. Antennae about  $2\frac{1}{4}$  times as long as width of head. Thorax scarcely arched. Hind tibia with small basal spur. Forewings large, membrane set with numerous very small setae, veins bearing small setae,  $2\frac{1}{3}$  times as long as wide; venation typical, Rs curved, pterostigma almost obsolete.

GENITALIA: Male proctiger long, slightly narrowed and bent caudad in apical third. Forceps shorter than proctiger; in lateral view slender, straight; in caudal view slender, slightly arched, apices black, acute, many long silky setae on caudal and medial margins. Female genital segment longer than rest of abdomen (much longer in dry specimens); ventral valve elongate, acute, upcurved; dorsal valve attenuate, longer than ventral, dorsal margin sinuate, apex blunt, slightly upcurved.

This species was described from one pair from Ohio. I have taken it in great numbers in Minnesota on hazel brush (*Corylus* sp.) during August. Specimens are also before me from Wisconsin; Onaga, Kansas; Ormsby County, Nevada; Humboldt and Marin County, California (Koebele, on *Corylus rostrata*). The latter specimens are those mentioned by Crawford as a varietal form of *striata* and inadvertently named *Psylla coryli* by him. This name was preoccupied by *P. coryli* Patch; thus Caldwell's name stands for the species.

TYPE, male, Fulton Co., Ohio, H. Osborn, in Ohio Biological Survey Collection, Ohio State University, Columbus, Ohio.

Host *Corylus* sp.

*Psylla striata*† Patch

(Figs. 24, 25)

1911 *Psylla striata* Patch, Me. Agr. Exp. Sta., Bull. 187:14-15.1914 *Psylla striata* Crawford, U. S. Nat. Mus., Bull. 85:138, 150.1917 *Psyllia striata* Van Duzee, Cat. Hemip. N. Am. 809.1922 *Psyllia striata* Osborn, N. Y. St. Coll. For., Tech. Pub. 16:53.1923 *Psylla striata* Patch, Hemip. Conn. 249.1932 *Psyllia striata* Klyver, Ent. News 43:73.1938 *Psylla striata* Brimley, Ins. N. C. 104.1938 *Psyllia striata* Strickland, Can. Ent. 70:205.

\* From *di*, L. — two + *lonchus* — *i*, L. m. noun — lance, — *i* is the correct plural ending.

† *P.* part. of *strio*, L. v.—wrinkled, striated.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: Yellow, including wings, sometimes greenish. Apical third of antennae dark.

STRUCTURE: Head small, strongly deflexed. Vertex over  $\frac{1}{2}$  as long as wide, discal depressions slight. Genal processes small, blunt, scarcely divergent,  $\frac{1}{2}$  as long as vertex. Antennae twice as long as width of head. Thorax well arched. Hind tibia with basal spur. Forewings with typical venation, about  $2\frac{1}{2}$  times as long as wide; Rs weakly sinuate, pterostigma prominent.

GENITALIA: Male proctiger slender, almost straight, very slightly curved caudad. Forceps in lateral view very narrow, straight; in caudal view slender, arched to acute black apices, medial margins with many long setae. Female genital segment twice as long as rest of abdomen; dorsal valve much longer than ventral, apical half attenuate with dorsal margin straight, apex blunt; ventral valve acute.

Numerous specimens are at hand from Massachusetts, New Hampshire, Nova Scotia, New York, Michigan, Wisconsin, South Dakota, Colorado, Utah, Washington, and British Columbia. It is also recorded from Connecticut, California, and Alberta.

Miss Patch described this species from *Betula* sp. (birch) and gives a few life history notes, the nymphs occurring on the leaves and terminal shoots of birch, covering themselves with inconspicuous woolly masses. The adults emerge late in June in Maine. Klyver records it as occurring in California on *Betula fontinalis*.

There is in the University of Kansas collection one female bearing a paratype label and the data: "Basswood, Ottawa Ont. 1-VII-1904, W. Metcalfe." This is obviously incorrectly labeled as the original description lists only specimens from Orono, Maine. This specimen is actually *P. diloncha* Caldwell.

### *Psylla brevistigmata*\* Patch

(Figs. 27, 28)

- 1912 *Psylla brevistigmata* Patch, Me. Agr. Exp. Sta., Bull. 202:222.  
1914 *Psylla brevistigmata* Crawford, U. S. Nat. Mus., Bull. 85:153.  
1914 *Psylla albirufa* Crawford, U. S. Nat. Mus. Bull. 85:153.  
1917 *Psylla brevistigmata* Van Duzee, Cat. Hemip. N. Am. 809.  
1925 *Psylla brevistigmata* Crawford, Proc. Haw. Ent. Soc. 6:30.  
1932 *Psylla brevistigmata* Klyver, Ent. News 43:73.

Length to tip of folded wings 2.5 to 3.25 mm.

COLOR: General color red with white markings as follows: Posterior and anterior margins of vertex, basal  $\frac{2}{3}$  of genal processes, posterior margin of pronotum and prescutum, six longitudinal stripes on scutum, margins of scutellum, margins of abdominal sclerites. Antennae dark distally. Wings somewhat fumate, pterostigma yellow. Variable from typical coloration to dark forms with genal processes, anterior portion of pronotum, venter of thorax, abdomen, and veins of forewings dark

\* From *brevis* -e, L. adj. — short + *stigma*, L. f. noun — mark.

brown. Forewings variable from almost hyaline through whitish to heavily infuscated.

**STRUCTURE:** Head broad, deflexed. Vertex pubescent on anterior margin, less than  $\frac{1}{2}$  as long as broad, very deeply impressed discally, anterior margin abrupt. Genal processes strongly divergent, subacute, nearly parallel to plane of vertex,  $\frac{2}{3}$  as long as vertex, prominently pubescent. Antennae twice as long as width of head. Thorax weakly arched. Hind tibia with prominent basal spur. Forewings long, over  $2\frac{1}{2}$  times as long as wide, often somewhat rugose; small radular areas on apical margin; venation typical, veins biserially setate, pterostigma broad but typically very short, somewhat variable.

**GENITALIA:** Male genitalia small. Proctiger in lateral view slender, curved caudad apically. Forceps shorter than proctiger; in lateral view slender, straight to acute black apices; in caudal view simple, slender, evenly arched to acute black apices, a fringe of stout setae on medial margins. Female genital segment subject to considerable variation in length, typically much shorter than rest of abdomen even in dried specimens, in some equalling rest of abdomen; dorsal valve longer than ventral, somewhat upturned, subacute; ventral valve evenly curved dorsad, apex acute.

The above description is written from California specimens, but many specimens are at hand from various western states. As may be expected in such an abundant species, considerable variation occurs in characters. In addition to color variations, the pterostigma is quite variable in length as is the female genital segment. It occurs in large numbers on its host plant, mountain mahogany (*Cercocarpus parvifolius*.)

Specimens are at hand from numerous localities in California, Arizona, Utah, Colorado, and New Mexico. The type specimens (two females) were from Sequoia National Park, California.

Crawford gives the length of the antennae as  $2\frac{3}{4}$  times the width of the head. I believe this to be a mistake as I have measured numerous individuals and have been unable to find any in which the antennae are more than slightly over twice as long as the width of the head.

*Psylla brevistigmata acuta*\* Crawford

1914 *Psylla brevistigmata acuta* Crawford, U. S. Nat. Mus., Bull. 85:139, 154.

1917 *Psyllia brevistigmata acuta* Van Duzee, Cat. Hemip. N. Am. 810.

Twelve specimens of this subspecies are at hand, all from Utah. They are uniformly much lighter in color than the typical subspecies, the genal processes are shorter (barely  $\frac{1}{2}$  as long as vertex), more blunt, and more divergent. The male forceps in lateral view tapered from midpoint, strongly bent mesad and cephalad as long slender black apices.

Specimens at hand are from Cedar City, Pintura, Weber Canyon, Providence Canyon, Logan Canyon, and Wasatch Mountains, Utah. One

\* *acutus* -a -um,, L. adj. — sharp, pointed.



of the Wasatch Mountains specimens (Koebele) bears a label *Cercocarpus ledifolius*.

TYPE, male, No. 18112 United States National Museum.

Type examined.

*Psylla insignita*\* n. sp.

(Figs. 55, 56, 278)

Length to tip of folded wings 3.25 to 3.50 mm.

COLOR: General color red. More or less distinct white markings as in *brevistigmata*.

STRUCTURE: Similar to *brevistigmata* except genal processes much larger, almost as long as vertex.

GENITALIA: Male proctiger long, stout, parallel-sided. Forceps in lateral view long, slightly swollen apically; in caudal view nearly straight to near apex, turned sharply mesad as black, heavy, sharp apices; in dorsal view apices rounded, bearing a large somewhat Y-shaped black tooth, extending mesad. Female genital segment very large, as long as rest of abdomen or longer; dorsal valve slightly longer than ventral, blunt.

The exact relationship of this form to *brevistigmata* is uncertain, but as it is distinct and readily recognizable it is described as a species of the somewhat confusing *brevistigmata* complex.

Described from numerous males and females bearing data as follows: Salt Lake City, Utah, July 3, 1931; Weber Canyon, Utah, July 4, 1931; Fish Lake, Utah, Aug. 16, 1929; Bray, California, June 30, 1935; all specimens collected by R. H. Beamer; two females from Bray, California, June 30, 1935, P. W. Oman.

HOLOTYPE, male, ALLOTYPE, female, Salt Lake City, Utah, in Snow Collection, University of Kansas. Paratypes in Snow Collection, United States National Museum, and author's collection.

The females from Bray, California, have an extremely large genital segment the valves of which are somewhat different in shape from the Utah specimens, but the males appear to be identical.

*Psylla magna*† Crawford

(Figs. 57, 58)

1914 *Psylla brevistigmata magna* Crawford, U. S. Nat. Mus., Bull. 85:139, 154.

1917 *Psyllia brevistigmata magna* Van Duzee, Cat. Hemip. N. Am. 809.

Similar to *brevistigmata* except in genitalia and size.

Length to tip of folded wings 3.5 mm.

GENITALIA: Male proctiger short; in lateral view straight, broad, excavate on caudal margin apically. Forceps in lateral view nearly straight, enlarged apically, a deep, rounded cleft in apices, anterior lobe short, rounded, posterior lobe ending in a large, black, acute tooth extending antero-mesally; in caudal view weakly arched to black apices. Female

\* *insignitus* -a -um, L. adj.—striking, remarkable.

† *magnus* -a -um, L. adj.—large.



genital segment very short and turned ventrad; dorsal valve slightly longer than ventral, apex blunt.

Crawford described this form as a variety, but due to the very distinct and constant genital characters I am raising it to specific rank.

Numerous specimens are at hand from Bray, California; Carson City, Nevada; Fish Lake, Richfield, Weber Canyon, Zion National Park, and Pintura, Utah.

Host unknown, probably *Cercocarpus*.

TYPE, male, No. 18111, United States National Museum.

Type examined.

*Psylla omani*\* n. sp.

(Figs. 59, 60, 279)

Length to tip of folded wings 3 mm.

COLOR: General color light green to white. Flavous to orange markings on thorax. Wings whitish.

STRUCTURE: Head deflexed. Vertex broadly impressed discally, over  $\frac{1}{2}$  as long as wide. Lateral ocelli on raised areas. Genal processes slender, parallel to plane of vertex, scarcely divergent, blunt,  $\frac{2}{3}$  as long as vertex. Antennae twice as long as width of head. Thorax weakly arched. Pronotum strongly descending, long. Hind tibia with prominent basal spur. Forewings somewhat thickened,  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma short; radular areas at margin of marginal cells and between  $M_4$  and  $Cu_1$ . Membrane of hind wings set with minute setae.

GENITALIA: Male proctiger short, straight. Forceps with long heavy pubescence; in lateral view narrow basally then much enlarged on caudal margin, apices bearing a large, black, somewhat T-shaped tooth near cephalic margin; in caudal view bowed outward basally, deeply cleft, outer lobes slender, erect, acute, inner lobes, stout, bent mesad, then dorsad to black apices, a small hooked tooth apically. Female genital segment shorter than rest of abdomen, bent ventrad; dorsal valve curved, apex blunt; ventral valve equalling dorsal, spoon-shaped apically.

Described from two males and two females from Bray, California, June 30, 1935, P. W. Oman. Holotype and allotype in United States National Museum, paratypes in author's collection.

HOLOTYPE, male, No. 55169 United States National Museum.

It is with great pleasure that I dedicate this species to a friend and colleague, P. W. Oman, of the National Museum.

*Psylla hirsuta*† (Tuthill)

(Figs. 61, 62, 280)

1938 *Arytaina hirsuta* Tuthill, Ent. News, 49: 241-242.

Length to tip of folded wings 2 to 2.25 mm.

COLOR: General body color, including legs, red. Head and thoracic

\* In honor of P. W. Oman, homopterist of the United States National Museum.

† *hirsutus* -a -um, L. adj.—hairy.

dorsum with prominent white pubescence. Disc of vertex white, except medial line and two foveae black; antennae black at tip. Thoracic dorsum white, heavily marked with black and red; scutum definitely striped. Forewings reddish fumate, darker toward apex; veins red.

STRUCTURE: Head deflexed, slightly broader than thorax. Discal foveae and medial suture of vertex very prominent, postero-lateral portions of vertex, which bear ocelli, prominently raised. Genal processes blunt, pubescent, strongly divergent from base, scarcely touching basally,  $\frac{1}{3}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax heavily pubescent, granular. Posterior tibia with very small basal spur. Forewings twice as long as broad, coriaceous; venation typical, pterostigma short and broad.

GENITALIA: Male protigter longer than forceps, narrow in lateral view. Forceps in lateral view straight, parallel-margined; in caudal view strongly arched, apices notched, medial tooth thus formed, black, enlarged, extending antero-mesally. Female genital segment short, constricted midway and very narrow to apex; dorsal valve slightly longer than ventral.

This species is close to *Psylla coryli* but can readily be distinguished from it by the very heavy pubescence. The forewings are much more coriaceous and darker, the head is larger, and the female genital segment is different. Specimens are at hand from Oregon, Washington, California, Nevada, and Montana. Some of the California specimens bear labels identical with a series of *coryli*. A series from Satus Creek, Washington, April 23, 1938, K. Gray, bears the label "on *Purshia tridentata*."

HOLOTYPE, male, No. 55170 United States National Museum.

### *Psylla minuta*\* Crawford

(Fig. 26)

1914 *Psylla minuta* Crawford, U. S. Nat. Mus., Bull. 85:137, 142.

1914 *Psylla purshiae* Crawford U. S. Nat. Mus., Bull. 85:142.

1914 *Brachypsylla purshiae* Crawford, U. S. Nat. Mus., Bull. 85:142.

1917 *Psyllia minuta* Van Duzee, Cat. Hemip. N. Am. 806.

1931 *Psyllia minuta* Klyver, Pan-Pac. Ent. 7:158.

1932 *Psyllia minuta* Klyver, Ent. News 43:71.

Length to tip of folded wings 2.5 mm.

COLOR: General body color light to dark brown or red. Vertex, stripes on scutum, parts of remainder of thoracic dorsum, lighter. Wings more or less fumate, more heavily in apical half.

STRUCTURE: Vertex slightly more than  $\frac{1}{2}$  as long as wide, strongly bulging anteriorly, shallowly depressed discally. Genal processes cone-shaped, slender, acute, separated at base, divergent,  $\frac{2}{3}$  as long as vertex (typically). Antennae  $1\frac{2}{3}$  as long as width of head. Vertex and dorsum of thorax slightly pubescent. Basal spur on hind tibia very small, blunt. Forewings somewhat rugose,  $2\frac{1}{4}$  times as long as wide; venation typical, pterostigma long, large.

GENITALIA: Male protigter in lateral view narrow, longer than for-

\* *minutus* -a -um, L. adj.—small.

ceps. Forceps straight in lateral view; in caudal view arched to rather blunt, black apices; heavy pubescence, especially on mesal margins. Female genital segment as long as rest of abdomen; dorsal valve longer than ventral, both acute at apex.

This common species is represented in the material at hand by specimens from various localities in California, Arizona, Utah, Colorado, and Idaho. Klyver records it from Nevada also. As is to be expected in such an abundant species, the specimens show considerable variation, especially in color. The host plant is *Purshia tridentata*.

TYPE, female, No. 18108 United States National Museum, American Fork Canyon, Utah, Hubbard and Schwarz.

Type examined.

*Psylla coryli*\* Patch

1912 *Psylla coryli* Patch, Me. Agr. Exp. Sta., Bull. 202:223.

1914 *Psylla coryli* Crawford, U. S. Nat. Mus., Bull. 85:137, 143.

1917 *Psyllia coryli* Van Duzee, Cat. Hemip. N. Am. 806.

Length to tip of folded wings 2 to 2.25 mm.

COLOR: General color light brown to yellowish, thoracic dorsum dark brown except for light stripes. Posterior portion of vertex sometimes dark. Forewings yellowish fumate, more heavily so apically.

STRUCTURE: Vertex narrow, strongly depressed discally,  $\frac{2}{3}$  as long as wide, strongly overhanging anteriorly. Genal processes large, slightly over  $\frac{1}{2}$  as long as vertex, acute, divergent, almost parallel to plane of vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax very strongly arched. Only a very slight protuberance on base of hind tibia. Forewings of typical shape and venation, a little more than twice as long as wide; pterostigma broad, of moderate length.

GENITALIA: Male proctiger long, straight. Forceps small, straight, and parallel-sided in lateral view; in caudal view arched, each with a large black inner apical tooth, heavy setae on basal half of inner margins. Female genital segment as long as rest of abdomen; valves somewhat attenuate, dorsal longer than ventral, latter black-margined apically, somewhat flattened.

This species was described by Patch from one (?) male specimen from Colorado. Specimens are at hand from Colorado, Arizona, Nevada, California, Idaho, Oregon, Washington, and British Columbia.

Although Miss Patch's specimen is unavailable, her photograph of the male forceps plus Crawford's description make the identification of this species fairly certain.

TYPE, male, whereabouts unknown.

No indication of a host plant is given on any of the specimens.

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\* Genitive of *Corylus* -i, L. f. noun—a genus of plants (hazel).

*Psylla media*\* n. sp.

(Figs. 63, 64, 281)

Length to tip of folded wings 2.5 mm.

COLOR: Head and pronotum white with orange markings. Remainder of thorax mostly orange with markings lighter to white. Abdomen dark brown, sclerites white-margined. Forewings somewhat fumate, most heavily along veins M and Cu, whitish spots on margin in medial cell, between  $M_1$  and  $Cu_1$  and in cubital cell. Hind wings white.

STRUCTURE: Head small. Vertex  $\frac{3}{5}$  as long as wide, discal impressions broad and deep, deeply emarginate anteriorly. Genal processes cone-shaped, strongly divergent, blunt,  $\frac{1}{3}$  as long as vertex, nearly parallel to plane of vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax well arched. Pronotum long. Mesopleurites very strongly developed. Forewings long; venation typical, pterostigma very small. Basal spur on hind tibia extremely small.

GENITALIA: Male genitalia large. Proctiger short, stout, evenly narrowed to blunt apex. Forceps in lateral view broad, deeply cleft apically; caudal portion extending antero-mesally as a large, heavily sclerotized, obliquely truncate tooth, cephalic lobe rounded; in caudal view stout to cleft apices, well arched. Female genital segment  $\frac{1}{2}$  as long as rest of abdomen; dorsal valve sinuate on dorsal margin, apex slightly upturned, acute; ventral valve shorter than dorsal, acute.

Described from three females and one male from Trout Creek, Utah, May 8, 1934. T. O. Thatcher, taken on "*Carcocarpus aedifolius*"; one female, Green Canyon, Utah, April 22, 1934, T. O. Thatcher.

HOLOTYPE, female, No. 55171 United States National Museum.

*Psylla difficilis*† n. sp.

(Figs 29, 30)

Overall length 2 mm.

COLOR: General color of head and thoracic dorsum orange to white. Abdomen and venter of thorax fuscous. Forewings hyaline except pterostigma and borders of veins dark.

STRUCTURE: Head small. Vertex deeply impressed, about  $\frac{3}{4}$  as long as wide. Genal processes very short,  $\frac{1}{6}$  as long as vertex, blunt, separate basally. Antennae nearly twice as long as width of head (11.5:6.5). Thorax quite flat. Forewings very small; venation typical, pterostigma small. Hind tibia with small basal spur.

GENITALIA: Male genitalia very similar to *media*. Proctiger in lateral view stout, straight, caudal margin oblique apically. Forceps in lateral view straight, moderately broad, deeply cleft apically, lateral lobe rounded, caudo-mesal portion a black, curved hook; in caudal view stout, mesal teeth incurved, touching; in dorsal view mesal portion of forceps

\* *medius* -a -um, L. adj.—ambiguous.

† *difficilis* -e, L. adj.—troublesome.

is obliquely truncate apically. Female genital segment long ( $\frac{2}{3}$  as long as distended abdomen, longer than remainder of abdomen in normal dried specimens), dorsal and ventral valves both straight, slender, acute, nearly equal in length.

This species is quite similar to *media* but is distinct in the length of the antennae, the genal processes, the flatter thorax, and the genitalia of the female. The genitalia of the male are much like those of *media*. It is described from a series of eight males and females from Trident, Montana, Nov. 16, 1939, D. J. Pletsch, taken on mountain mahogany (*Cercocarpus*) and from specimens collected by D. D. Jensen at Pollock, Idaho. The Montana specimens have very small forewings which are much exceeded by the distended abdomens of males and females alike; the Idaho specimens have normal-sized forewings.

HOLOTYPE, male, ALLOTYPE, female, Trident, Montana, Nov. 16, 1939, D. J. Pletsch, in author's collection. PARATYPES with same data and from Pollock, Idaho, D. D. Jensen; paratypes in collections of Montana State College, author, and D. D. Jensen.

### *Psylla hartigii*\* Flor

(Figs. 31, 32)

- 1861 *Psylla hartigii* Flor, Rhynch. Liv. 2:450, 469.  
 1861 *Psylla hartigii* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 343, 351.  
 1874 *Psylla sylvicola* Lethierry, Cat. Hémip. Dept. Nord. 90 [*vide* Van Duzee].  
 1876 *Psylla sylvicola* Scott, Trans. Ent. Soc. London 1876:539.  
 1896 *Psylla hartigii* Edwards, Hemip.-Homop. Br. Is. 244, pl. XXVIII, fig. 4.  
 1908 *Psylla hartigii* Oshanin, Verz. palae. Hemip. 2:358.  
 1912 *Psylla hartigii* (?) Patch, Me. Agr. Exp. Sta., Bull. 202:222.  
 1912 *Psylla hartigii* Oshanin, Kat. palae. Hemip. 127.  
 1913 *Psylla hartigi* Aulmann, Psy. Cat. 16.  
 1914 *Psylla hartigii* Crawford, U. S. Nat. Mus., Bull. 85:146.  
 1917 *Psylla hartigi* Van Duzee, Cat. Hemip. N. Am. 807.  
 1932 *Psylla hartigii* Klyver, Ent. News 43:71.  
 1935 *Psylla hartigi* Haupt, Tierw. Mittel. 4, 3:235.  
 1938 *Psylla hartigii* Strickland, Can. Ent. 70:205.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: General color yellow to orange, darkest on dorsum. Antennae black apically. Forewings yellowish fumate.

STRUCTURE: Head small, not as strongly deflexed as in *striata*. Vertex slightly over  $\frac{1}{2}$  as long as wide, with very slight discal impressions. Genal processes acute, apices incurved, almost  $\frac{2}{3}$  as long as vertex. Antennae  $1\frac{2}{3}$  times as long as width of head (sometimes longer—Crawford). Thorax moderately arched. Hind tibia without basal spur. Forewings of average size, slightly less than  $2\frac{1}{2}$  times as long as wide; venation typical, Rs straight, pterostigma very large.

GENITALIA: Male protigter straight, narrow. Forceps in lateral view broad basally, quickly narrowed and very slender to apices; in caudal view slender, arched to apparently acute black apices; apices slightly bifid in caudal view. Female genital segment longer than rest of abdo-

\* Named in honor of Hartig, an early European entomologist.



men, slender, valves attenuate, ventral valve acute, straight, dorsal slightly longer than ventral, apical third very slender, downcurved.

Described from specimens from Lead, South Dakota, and Douglas Lake, Michigan. Originally described in Europe where it occurs on *Betula alba*, this apparently holarctic species was first recorded from North America by Miss Patch (Maine) on *Betula populifolia*. Additional records are New York, Nova Scotia, and Alberta. No host records are available on the specimens at hand, but the Lead, South Dakota, series was apparently taken with *P. striata*. Other than North America its known distribution is northern and central Europe.

Flor in describing this psyllid used the spelling *hartigii*. According to the international rules of nomenclature, when modern patronymics are originally published as ending in *ii* such names retain their original form even though they have been incorrectly formed (Op. 8).

*Psylla stricklandi*\* (Caldwell)

(Figs. 34, 35)

1939 *Psyllia stricklandi* Caldwell, Can. Ent. 71:212.

1939 *Psyllia stricklandi* Strickland, Can. Ent. 71:215.

Length to tip of folded wings 4 to 4.5 mm.

COLOR: General color green to yellow, fully mature specimens with brown markings on thorax, males darker. Antennae dark apically. Forewings slightly yellowish.

STRUCTURE: Head small. Vertex  $\frac{1}{2}$  as long as wide, posterior margin almost straight, discal impressions slight. Genal processes slender, blunt, divergent, as long as vertex at middle, vertical. Antennae slightly under twice as long as width of head. Thorax slightly arched. Posterior tibia with small basal spur. Forewings large, broad, barely over twice as long as wide, costal margin strongly arched; venation typical, pterostigma small.

GENITALIA: Male proctiger long, slender, bent caudad apically. Forceps as long as proctiger; nearly straight in lateral view to near apex, then narrowed (mostly on caudal margins) to blunt black apices; in caudal view slender, well arched, very long slender setae medially. Female genital segment longer than rest of abdomen; dorsal valve much longer than ventral, attenuate in apical half to slender, acute, slightly upturned apex, dorsal margin almost straight, styliform portion very densely radulate; ventral valve in lateral view acute, radulate apically.

Described from a pair of paratypes from Columbia Ice Field, Alberta (6,700 ft), July 22, on *Shepherdia canadensis*, and numerous adults and nymphs from Creede, Colorado, taken at about 10,000 to 11,000 feet; also in July on *Shepherdia canadensis* in 1938, 1939, and 1940. In general, the Colorado specimens are lighter in color than the paratypes.

TYPE, female, in Canadian National Collection, Ottawa, Ontario.

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\* Named in honor of E. H. Strickland, the collector.



*Psylla tuthilli*\* (Caldwell)

(Fig. 33)

1939 *Psylla virida* Caldwell, Can. Ent. 71:212.[non] *Psylla viridis* Hartig, Germ. Zeitschr. Ent. 3:374. 1841.1939 *Psylla virida* Strickland, Can. Ent. 71:215.1940 *Psylla tuthilli* Caldwell, Ohio Jour. Sci., 40:50.

"Length to tip of forewing 3 to 3.5 mm.; forewing 2.7 to 3.3 mm.

"Color: Appearing yellow-green throughout; antennae black at joints and distally; forewings yellowish; genital segment brownish.

"Genal cones longer, more divergent, and more slender than in *stricklandi*. Forewings with  $Cu_1$  rather arched, similar to *carpinicola* Crawford.

"Genitalia: Female segment longer than rest of abdomen. Dorsal valve styliform for caudal third, this portion minutely roughened; caudal half of styliform portion abruptly turned up; apex blunt. Ventral valve almost as long as dorsal; very strongly hooked dorsad in lateral aspect. Lateral plates no longer than ventral valve.

"Forceps of male attenuate in apical third in caudal aspect, in lateral aspect appearing very slender and gradually narrowed to apex."—Caldwell.

This species was described from a single female and several males. I have examined one male paratype and find it to be very similar to *P. magnicauda*. The genal processes are more slender than on the latter species, the antennae slightly shorter proportionately, slight differences are apparent in the venation, etc., but nothing of any marked distinction. Caldwell writes that the female was quite distinct, however, and was therefore made the type, that the dorsal and ventral valves of the female genital segment are much more upturned than they are in *magnicauda*, that the valves are nearly the same length, and that the lateral plates do not exceed the ventral valve as they do in *magnicauda*.

Host *Shepherdia argentea*, "Bullberry" (Strickland).

TYPE, female, August 7, 1938, Medicine Hat, Alberta, in Canadian National Collection, Ottawa, Ontario.

*Psylla magnicauda*† Crawford

(Figs. 36, 37)

1914 *Psylla magnicauda* Crawford, U. S. Nat. Mus., Bull. 85:138, 149.1914 *Psylla americana abdominalis* Crawford, U. S. Nat. Mus., Bull. 85:150.1917 *Psylla magnicauda* Van Duzee, Cat. Hemip. N. Am. 809.1932 *Psylla magnicauda* Klyver, Ent. News 43:72.1938 *Psylla magnicauda* Strickland, Can. Ent. 70:205.1939 *Psylla magnicauda* Strickland, Can. Ent. 71:215.

Length to tip of folded wings 3.5 to 4.25 mm.

COLOR: Uniformly light green or slightly yellowish, occasionally faint, longitudinal stripes on scutum. Head often whitish. Forewings clear or slightly yellow.

\* Named in honor of L. D. Tuthill.

† From *magnus* -a -um, L. adj.—large + *cauda* -ae, L. f. noun—tail.

**STRUCTURE:** Head strongly depressed, vertex almost perpendicular. Vertex  $\frac{1}{2}$  as long as wide, rounded down anteriorly, discal impressions prominent. Genal processes large, slender, cone-shaped, about as long as vertex. Antennae almost twice as long as width of head. Thorax well arched. Hind tibia with small basal spur. Forewings broad, less than  $2\frac{1}{2}$  times as long as wide; marginal cells large, Rs sinuate, pterostigma small.

**GENITALIA:** Male proctiger slender, apical fourth bent caudad. Forceps large, almost as long as proctiger; in lateral view parallel margined; in caudal view slender, arched to black, blunt apices. Female genital segment large and very thick dorso-ventrally, as long as rest of abdomen or longer; dorsal margin of dorsal valve sinuate, apex slender, elongate, radulate, apex upturned; ventral valve much shorter than dorsal, acute, slightly upcurved; lateral plates longer than ventral valve.

Numerous specimens are at hand from Colorado, Wyoming, Montana, North Dakota, Minnesota, British Columbia, Saskatchewan, Manitoba. It is also recorded from California and Alberta. Strickland gives the host of this abundant and widespread species as *Eleagnus commutata* (*Eleagnus argentea*), wolf willow. In Colorado I have taken it on *Shepherdia argentea*.

**TYPE**, female, Sheridan, Wyoming, Metz, is in the Crawford collection and also bears the type label of *Psylla americana abdominalis*.

### *Psylla buxi*\* (Linnaeus)

(Fig. 38)

- 1758 *Chermes buxi* Linnaeus, Syst. Nat. 10:454.  
 1848 *Psylla buxi* Förster, Verh. natur. Ver. preuss. Rhein. 5:71.  
 1872 *Psylla buxi* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:399.  
 1876 *Psylla buxi* Scott, Trans. Ent. Soc. London 1876:534.  
 1890 *Psylla buxi* Riley, 5th Rept. U. S. Ent. Comm. 672 [rept. of discovery in N. Y., 1881].  
 1896 *Psylla buxi* Edwards, Hemip.-Homop. Br. Is. 249, pl. XXVIII, fig. 7.  
 1908 *Psylla buxi* Oshanin, Verz. palae. Hemip. 2:357.  
 1910 *Psylla buxi* Smith, Ins. N. J. 109.  
 1912 *Psylla buxi* Oshanin, Kat. palae Hemip. 127.  
 1913 *Psylla buxi* Aulmann, Psy. Cat. 11.  
 1916 *Psylla buxi* Britton, 39th Rept. Conn. Agr. Exp. Sta. 186.  
 1917 *Psylla buxi* Weiss and Dickerson, Ent. News 28:40-41.  
 1917 *Psyllia buxi* Van Duzee, Cat. Hemip. N. Am. 811.  
 1921 *Asphagidella buxi* Enderlein, Zool. Anz. 52:120.  
 1926 *Asphagidella buxi* Enderlein, Ent. Mitt. 15:399.  
 1926 *Psyllia buxi* Ferris, Can. Ent. 58:19 [desc. and figs. nymph].  
 1932 *Psyllia buxi* Klyver, Ent. News 43:75.  
 1938 *Psyllia buxi* Caldwell, Ohio Biol. Surv., Bull. 34:265.

Length to tip of folded wings 3.5 to 4 mm.

**COLOR:** General color light green, more or less brown on dorsum and pleurites of thorax, pro- and mesothoracic femora partly embrowned. Forewings slightly yellowish. Hind wings white.

**STRUCTURE:** Head large, deflexed about  $45^\circ$ . Vertex  $\frac{3}{5}$  as long as wide, with very prominent discal foveae, a sharp sulcus extending from

\* Genitive of *Buxus* -i, L. f. noun—the box-tree (the host plant).

each medio-anteriorly to near anterior margin. Genal processes very large, robust, blunt,  $\frac{1}{2}$  as long as vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax well arched. Posterior tibia with large basal spur and small tubercle. Forewings large, much longer than body, somewhat over  $1\frac{1}{2}$  times as long as wide; membrane thickly set with minute setae; marginal cells large, Rs long, curved, pterostigma almost entirely lacking.

GENITALIA: Male proctiger longer than forceps, almost straight. Forceps in lateral view broad, straight, slightly enlarged toward apices; in caudal view stout, slightly arched, apices flattened, incurved, terminating in a large, curved, black tooth. Female genital segment twice as long as rest of abdomen, dorsal valve much longer than ventral, downcurved, apex acute, upturned; ventral valve acute, upturned.

Described from a series of specimens from New York on "*Bux.*" Additional specimens are at hand from Portland, Oregon. It is also recorded from New Jersey, Ohio, Connecticut, and California. Outside of North America its known distribution embraces Great Britain and almost all of continental Europe.

The male specimens at hand are all somewhat teneral, hence the description of the male genitalia may be erroneous in some details.

Enderlein (1921) designated *P. buxi* as type of a new genus, *Asphagidella*, based on the lack of pterostigma in the forewing and venational characteristics of the hind wings, characters which I do not believe to be of generic significance.

This species causes considerable injury to its host, ornamental box (*Buxus sempervirens*).

*Psylla bulbosa*\* n. sp.

(Figs. 67, 68, 283)

Length to tip of folded wings 2.75 to 3 mm.

COLOR: Whitish green, scutum and anterior portion of prescutum sometimes yellowish. Forewings slightly fumate. Tip of antennae dark.

STRUCTURE: Head strongly deflexed. Vertex almost plane, slightly over  $\frac{1}{2}$  as long as wide. Genal processes large, swollen, rounded, contiguous most of length,  $\frac{3}{4}$  as long as vertex, scarcely depressed below plane of vertex, nearly parallel. Antennae  $1\frac{1}{3}$  times as long as width of head. Thorax broad, well arched. Hind tibia with prominent spur at base. Forewings broad, but slightly over twice as long as wide; venation typical, pterostigma very broad, of moderate length. Membrane of both fore and hind wings thickly set with minute setae, forming indefinite radular areas on margin of forewing.

GENITALIA: Male genitalia large. Subgenital plate unusually large. Proctiger straight, narrow. Forceps nearly reaching tip of proctiger, with long heavy pubescence; in lateral view narrow, slightly sinuate on caudal margin; in caudal view arched to blunt, black apices, somewhat flattened on caudal side near apex; in dorsal view apices truncate, pro-

\* *bulbosus* -a -um, L. adj.—bulbous, in reference to the genal processes.

duced cephalad as small blunt tooth. Female genital segment heavy, longer than rest of abdomen, with long sparse pubescence; dorsal valve longer than ventral, nearly straight, apex subacute, upturned, apical portion radulate; ventral valve nearly straight, acute.

Described from twenty-two specimens from Ruby, Arizona, July 22, 1938, R. H. Beamer, collected on *Salix taxifolia* H.B.K., in the Snow Collection, University of Kansas, and twenty-six specimens in the United States National Museum, twenty-one of which bear a label, "Turkey Creek, Arizona, June 10, 1933, P. W. Oman"; the remaining five are from Nogales, Arizona, June 25, 1933, P. W. Oman.

HOLOTYPE, male, ALLOTYPE, female, and paratypes in Snow Collection; paratypes in United States National Museum and author's collection.

*Psylla manisi*\* n. sp.

(Figs. 69, 70, 284)

Length to tip of folded wings 3.5 mm.

COLOR: General color reddish, genal processes and legs lighter. Antennae black apically. Forewings fumate, most heavily along veins and apically; pterostigma yellowish opaque.

STRUCTURE: Head strongly deflexed. Head and thorax punctate. Vertex long, over  $\frac{1}{2}$  as long as wide, slight discal impressions. Genal processes stout, contiguous almost to tips,  $\frac{1}{2}$  as long as vertex. Antennae slightly longer than width of head. Thorax well arched. Pronotum almost vertical. Hind tibia with small basal tubercle. Forewings slightly over  $2\frac{1}{2}$  times as long as wide; membrane very thickly set with minute setae; cubital cell larger than medial, pterostigma very large.

GENITALIA: Male proctiger much longer than forceps, near apex narrowed and flexed caudad. Forceps in lateral view broad basally, much enlarged, then converging (more abrupt on caudal margin) to narrow, cephalically turned, sharp, black apices; in caudal view very broad basally, mesal margins sinuate, lateral margins nearly straight  $\frac{2}{3}$  of length then sharply excavate, slender brown apical portion slightly incurved, sharp lateral margins near base produced caudad as a small flat lobe. Female genital segment shorter than rest of abdomen (much shorter in fresh or alcoholic specimens); dorsal valve slightly upcurved, blunt; ventral valve shorter than dorsal, deep, ventral margin straight to mid-point then angularly bent dorsad to acute apex.

Described from a series of thirty-seven males and females sent to me by H. C. Manis of the University of Idaho, to whom the species is dedicated. They were collected on mountain ash on Moscow Mountain near Moscow, Idaho, September 5, 1940. Three additional females from the same locality were collected in July and August, 1938, by H. M. Harris.

HOLOTYPE, male, ALLOTYPE, female, and PARATYPES in author's collection; paratypes in United States National Museum and University of Kansas.

\* Named in honor of H. C. Manis, the collector.

*Psylla breviata*\* Patch

(Figs. 39, 40)

1912 *Psylla breviata* Patch, Me. Agr. Exp. Sta., Bull. 202:220.1914 *Psylla breviata* Crawford, U. S. Nat. Mus., Bull. 85:137, 141.1917 *Psyllia breviata* Van Duzee, Cat. Hemip. N. Am. 806.1931 *Psyllia breviata* Klyver, (?) Pan-Pac. Ent. 7:157.

Length to tip of folded wings 3 mm.

COLOR: Greenish yellow throughout except tip of antennae dark. Wings slightly whitish.

STRUCTURE: Head strongly deflexed. Vertex with prominent discal impressions,  $\frac{2}{3}$  as long as wide. Genal processes slender, straight, blunt,  $\frac{3}{4}$  as long as vertex. Antennae but very slightly longer than width of head. Thorax well arched. Pronotum nearly vertical. Hind tibia with small, blunt basal spur. Forewings broad, but slightly over twice as long as wide; venation typical, pterostigma large. Membrane of both fore- and hind wings very thickly set with minute setae.

GENITALIA: Male proctiger long, straight. Forceps in lateral view long, straight to near apex than excavate on cephalic margin; in caudal view bowed basally, nearly straight to near apex then sharply bent mesad; apices slender, acute, curving cephalad. Female genital segment about as long as rest of abdomen, stout; dorsal valve longer than ventral, attenuate, slightly upcurved and knoblike apically; ventral valve acute.

One female is at hand from Marquette, Michigan, and a large series of males and females from California (Placer and Nevada Counties and Argus Mountains). The description of the male genitalia is from the latter group. That the California specimens are Miss Patch's species I believe is quite doubtful, but until some males are available from the type locality they are placed here. The original description was based on three females from Dows Swamp, Ottawa, Ontario, June 14, 1903. Host unknown.

From the figure of the male genitalia accompanying Klyver's records of *breviata* from Utah and Nevada, his specimens apparently are not the same species. I believe them to be a heretofore undescribed species *Psylla manis*.

*Psylla quadrilineata*† Fitch

(Figs. 71, 72)

1851 *Psylla quadrilineata* Fitch, 4th Rept. N. Y. Sta. Mus. 64.1885 *Psylla quadrilineata* Riley, Proc. Biol. Soc. Wash. 2:69.1890 *Psylla quadrilineata* Provancher, Pet. Faune Ent. Can. 305-306.1893 *Psylla quadrilineata* Fitch, 46th Rept. N. Y. Sta. Mus. (reprint of original desc.).1913 *Psylla quadrilineata* Aulmann, Psy. Cat. 25.1914 *Psylla quadrilineata* Crawford, U. S. Nat. Mus., Bull. 85:148.1917 *Psyllia quadrilineata* Van Duzee, Cat. Hemip. N. Am. 808.

Length to tip of folded wings 3 mm.

COLOR: General color red to reddish brown. Lighter on margins of

\* *breviatus*, L. (p. part. of *brevio*)—shortened.

† From *quadri*-, L.—four + *lineatus*, L. (p. part. of *lineo*)—striped.



most sclerites. Four light longitudinal stripes on scutum. Wings slightly whitish, pterostigma infuscated.

**STRUCTURE:** Head and thorax coarsely punctate. Head large, strongly deflexed. Vertex  $\frac{2}{3}$  as long as wide, posterior margin deeply concave, deeply impressed discally, anterior margin very strongly protruding, overhanging median ocellus. Genal processes stout, straight, blunt, scarcely tapered,  $\frac{1}{2}$  as long as vertex. Antennae short, thick, as long as width of head. Thorax moderately arched. Legs short. Hind tibia with short, stout, basal spur. Membrane of both fore- and hind wings thickly set with minute setae, in forewing forming indefinite radular areas on apical margin. Forewings slightly less than  $2\frac{1}{2}$  times as long as wide; marginal cells unusually large; Rs very long, pterostigma very large.

**GENITALIA:** Male proctiger stout, straight, parallel-margined, with an anterior projection basally and an apical epiphysis. Forceps in lateral view moderately broad basally, enlarged, slightly constricted beyond midpoint, apical portion sharply constricted and flexed caudad to truncate black apices; meso-apical margin produced anteriorly as a small black tooth; in caudal view evenly arched from bases to acute black apices, broadest midway. Female genital segment  $\frac{1}{4}$  shorter than rest of abdomen; dorsal valve straight, apical portion attenuate, blunt; ventral valve shorter, upturned midway, acute.

Described from five females and one male from New Hampshire which have been compared with the type. The TYPE, a female, No. 1342 United States National Museum, and two females of Fitch's type series are in the National Museum. They have been molded but are in fair condition. This species is similar to *P. americana* in many respects.

The host is unknown.

### *Psylla mali*\* (Schmidberger)

(Figs. 41, 42)

- 1836 *Chermes mali* Schmidberger, Beitr. z. Nat. Schäd. Ins. 4:186 [*vide* Aulmann].
- 1848 *Psylla mali* Förster, Verh. natur. Ver. preuss. Rhein. 5:72.
- 1848 *Psylla ulmi* Förster, Verh. natur. Ver. preuss. Rhein. 5:71.
- 1848 *Psylla pomi* Förster, Verh. natur. Ver. preuss. Rhein. 5:72.
- 1848 *Psylla crataegicola* Förster, Verh. natur. Ver. preuss. Rhein. 5:72.
- 1848 *Psylla aeruginosa* Förster, Verh. natur. Ver. preuss. Rhein. 5:97.
- 1848 *Psylla occulta* Förster, Verh. natur. Ver. preuss. Rhein. 5:98.
- 1848 *Psylla dubia* Förster, Verh. natur. Ver. preuss. Rhein. 5:73.
- 1861 *Psylla mali* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 345, 350, 358.
- 1872 *Psylla mali* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:398.
- 1872 *Psylla rubida* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:398.
- 1872 *Psylla claripennis* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:400.
- 1876 *Psylla mali* Scott, Trans. Ent. Soc. London 1876:542.
- 1878 *Psylla mali* Löw, Verh. zool.-bot. Ges. Wien 27:135.
- 1876 *Psylla crataegicola* Scott, Trans. Ent. Soc. London 1876:542.
- 1876 *Psylla viridissima* Scott, Trans. Ent. Soc. London 1876:543.
- 1908 *Psylla mali* Oshanin, Verz. palae. Hemip. 2:355.
- 1910 *Psylla mali* Oshanin, Verz. palae. Hemip. 3:191.
- 1912 *Psylla mali* Oshanin, Kat. palae. Hemip. 127.

\* Genitive of *malus*—the apple, its principal host.



1913 *Psylla mali* Aulmann, Psy. Cat. 19.

1919 *Psyllia mali* Brittain, Agr. Gaz. Can. 6:823-827 [figs].

1923 *Psyllia mali* Brittain, N. S. Dept. Agr., Bull. 10:1-69, VI pls. [life history, control].

1931 *Psylla mali* Klyver, Can. Ent. 63:114.

1935 *Psylla mali* Haupt, Tierw. Mittel. 5:236.

Length to tip of folded wings 4 mm.

COLOR: "Summer coloration. General color pale green, sometimes tinged with yellow; no color difference exists between the sexes in the early part of the season. . . .

"Autumn coloration, female. . . Head varying from bright yellow to dark brown with local modulations; median suture always darker . . . Prothorax, dull yellow varying to dark brown; reddish and dusky markings may occur. Praescutum of mesothorax orange to brown, sometimes greenish; anterior portion usually darker. . . . Scutum, dull yellow to dark orange, dark brown where yellow bars existed in summer coloration. Remainder of thorax, dull yellow and orange with dusky markings varying in location and intensity. Abdomen; the yellow posterior margin of the dorsum of each segment becomes orange or deep blood red, . . . (rest) dusky or jet black. . . . Entire ventral surface of body uniform dull yellow. . . .

"MALE. General body color changed from green to bright orange yellow."—Brittain.

STRUCTURE: Head very strongly deflexed, almost perpendicular to axis of body. Vertex with shallow discal impressions, bulging anteriorly,  $\frac{1}{2}$  as long as wide. Genal processes divergent, slender, blunt, almost as long as vertex. Antennae small,  $1\frac{3}{4}$  times as long as width of head. Thorax strongly arched. Legs small; hind tibia with small basal spur. Forewings somewhat whitish,  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma very large. Membrane of fore- and hind wings thickly set with minute setae.

GENITALIA: Male genitalia small. Proctiger short, slightly longer than forceps, strongly bent caudad near apex. Forceps simple, slightly arched to blunt, black, apices. Female genital segment shorter than rest of abdomen, stout; dorsal valve blunt, slightly longer than ventral, latter acute.

Described from a short series from Digby and Kings Counties, Nova Scotia, collected by W. H. Brittain, July, 1931, and determined by Oman as *Psylla mali*. I have not seen any European specimens.

Brittain has done a great amount of work on this pest since its discovery in Nova Scotia in 1919. It is treated in detail in Bulletin No. 10 of the Department of Agriculture of Nova Scotia. Briefly, the life history in Nova Scotia is as follows: The eggs are deposited in the fall (September and October). Hatching occurs early in May. The average nymphal life is 34 days, the adults appearing in the last half of June. Mating occurs within a fortnight of emergence and continues for the next two months. There is but one generation per year.

As indicated above the color changes as the season progresses, from a pale green to brown and vivid orange or red.

To date it has been recorded only from Nova Scotia and New Brunswick in North America. It is generally distributed through northern and central Europe and Asia including Japan.

*Psylla alba*\* Crawford

(Figs. 43, 44)

- 1914 *Psylla alba* Crawford, U. S. Nat. Mus., Bull. 85:138, 143.  
 1914 *Psylla americana alba* Crawford, U. S. Nat. Mus., Bull. 85:143.  
 1917 *Psyllia alba* Van Duzee, Cat. Hemip. N. Am. 806.  
 1932 *Psyllia alba* Klyver, Ent. News 43:71.  
 1938 *Psyllia alba* Strickland, Can. Ent. 70:204.

Length to tip of folded wings 3 mm.

COLOR: Typically greenish white, some specimens (faded?) yellowish.

STRUCTURE: Vertex a little over  $\frac{1}{2}$  as long as wide, strongly bulging anteriorly, with shallow discal impressions. Genal processes almost as long as vertex, heavy, contiguous basally, rather blunt. Antennae a little more than  $1\frac{1}{2}$  times as long as width of head. Thorax typical. A small basal spur on hind tibia. Forewings large, whitish, transparent; over twice as long as wide; venation typical, pterostigma large.

GENITALIA: Male proctiger long and slender, straight. Forceps small, much shorter than proctiger, stout; in caudal view almost straight to near apices, a large, black, incurved tooth at apex of each. Female genital segment as long as rest of abdomen, dorsal valve a little longer than ventral, both acute.

Described from specimens from Nicolaus, California, which have been compared with the type. Specimens are at hand from California, Washington, Utah, Wyoming, Colorado, and Wisconsin.

TYPE, female, Ormsby County, Nevada, July, Baker, in the Crawford Collection.

The host is *Salix* sp.

*Psylla ribesiae*† Crawford

(Figs. 45, 46)

- 1911 *Psyllopa ribesiae* Crawford, Pom. Coll. Jour. Ent. 3:630-631.  
 1912 *Psylla gilletti* Patch, Me. Agr. Exp. Sta., Bull. 202:221.  
 1914 *Arytaina ribesiae* Crawford, U. S. Nat. Mus., Bull. 85:126.  
 1914 *Psylla ribis* Crawford, U. S. Nat. Mus., Bull. 85:127.  
 [non] *Psylla ribis* Patch, Me. Agr. Exp. Sta., Bull. 202:222. 1912.  
 1917 *Arytaina ribesiae* Van Duzee, Cat. Hemip. N. Am. 804.  
 1932 *Arytaina ribesiae* Klyver, Ent. News, 43:39-40.

Length to tip of folded wings 3.25 to 4 mm.

COLOR: Quite variable. From light to dark brown, usually dark. Scutum with light and dark stripes. Vertex white with variable dark markings. Genital processes white. Antennae dark distally, tips of basal

\* *albus* -a -um, L. adj.—white.

† Etymology obscure; apparently based on *Ribes*, the generic name of the host.

segments dark. Forewings clear except for a prominent dark spot at apex of clavus, sometimes a brownish area at base, four more-or-less prominent spots on margin.

**STRUCTURE:** Head large, very strongly deflexed. Vertex shallowly impressed discally,  $3/5$  as long as wide. Genal processes almost on same plane as vertex, somewhat divergent then incurved slightly, blunt, quite variable in shape and size, usually about  $2/3$  as long as vertex. Antennae  $1\frac{3}{4}$  times as long as width of head. Thorax strongly arched. Hind tibia with small basal spur. Forewings about  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma small; four radular areas along margin, in cubital cell, between  $Cu_1$  and  $M_4$ , in medial cell, between  $M_1$  and  $Rs$ .

**GENITALIA:** Male proctiger stout, straight, length somewhat variable. Forceps in lateral view broad basally, unevenly narrowed to slender truncate apices, turned caudad at apex; in caudal view broad, slightly arched. (Quite variable in size and exact shape.) Female genital segment shorter than rest of abdomen, stout; valves almost equal in length, acute, ventral valve strongly upcurved.

This is a numerous and widespread species occurring over western North America. It is extremely variable in almost all characters, especially color, genal processes, and genitalia, which makes it very difficult to define. In addition to a paratype from Boulder, Colorado, specimens are at hand from numerous localities in the following states: Colorado, Kansas, Nebraska, South Dakota, Wyoming, Idaho, Arizona, California, and Oregon.

Klyver records *Ceanothus thyrsiflorus* as a definite host in California. Many of the specimens at hand bear labels "*currant*," *Ribes*, *Ribes aureum*. Many of the specimens so labeled are teneral and have cast nymphal skins or nymphs on the pin with them. It would seem, therefore, as if hosts in at least two different genera were capable of supporting this common form. Many of the specimens from which Patch described *gilletti* are in the collection of the Colorado Agricultural College and have been examined.

Crawford placed this species in *Arytaina* apparently because of the position of the genal processes in which character it resembles some members of that genus. The chief distinction between the two genera, however, is the shape of the prothoracic pleurites. On this basis *ribesiae* must go in the genus *Psylla* to which it is similar in most respects. In many specimens a slight groove on the episternum is pigmented and on superficial examination the propleurites do have the appearance of being equal in length and in breadth dorsally. Several other species of *Psylla* exhibit this same character, and in those forms in which the head extends well back over the prothorax laterally, it becomes quite difficult to ascertain the exact condition of these sclerites without dissection.

**TYPE**, female, Boulder, Colorado, Bethel, *Ribes longiflorum*, in the Crawford Collection.

*Psylla pyricola*\* Förster

(Figs. 4, 5, 47, 48)

- 1840 *Psylla pyri* Curtis, Gard. Chron. 156 (nec Linn. Faun. Svec. 1761) [*fide* Aulmann, Psy. Cat. 24].
- 1848 *Psylla pyricola* Förster, Verh. natur. Ver. preuss. Rhein. 5:77-78.
- 1848 *Psylla apiophila* Förster, Verh. natur. Ver. preuss. Rhein. 5:78.
- 1861 *Psylla notata* Flor, Bull. Soc. Imp. Nat. Moscou 34:341, 349, 355, 365-367.
- 1872 *Psylla pyricola* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:396.
- 1872 *Psylla apiophila* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:396.
- 1880 *Psylla pyrisuga* Barnard, Proc. A.A.A.S. 28:478-486.
- 1885 *Psylla pyricola* Riley, Proc. Biol. Soc. Wash. 2:69.
- 1892 *Psylla pyricola simulans* Slingerland, N. Y. (Cornell) Agr. Exp. Sta., Bull. 44:175, 185.
- 1893 *Psylla pyricola* Lintner, 9th Rept. N. Y. Sta. Ent. 317-329.
- 1908 *Psylla pyricola* Oshanin, Verz. palae. Hemip. 2:352.
- 1910 *Psylla pyricola* Oshanin, Verz. palae. Hemip. 3:189.
- 1910 *Psylla pyricola* Smith, Ins. N. J. 109.
- 1911 *Psylla pyricola* Patch, Me. Agr. Exp. Sta., Bull. 187:11.
- 1912 *Psylla pyricola* Oshanin, Kat. palae. Hemip. 127.
- 1913 *Psylla pyricola* Aulmann, Psy. Cat. 24.
- 1914 *Psylla pyricola* Crawford, U. S. Nat. Mus., Bull. 85:144.
- 1917 *Psylla pyricola* Van Duzee, Cat. Hemip. N. Am. 806.
- 1918 *Psylla pyricola* Ross, 49th Ann. Rept. Ent. Soc. Ont. 81.
- 1931 *Psylla pyricola* Klyver, Can. Ent. 63:112.
- 1938 *Psylla pyricola* Caldwell, Ohio Biol. Surv., Bull. 34:261.
- 1938 *Psylla pyricola* Brimley, Ins. N. C. 104.

Length to tip of folded wings (summer form) 2.0 to 2.75 mm., (winter form) 3.3 to 4 mm. (Crawford).

COLOR: SUMMER FORM. "General color light orange to reddish brown, with darker markings; vertex, genal cones, scutum between stripes, male genitalia, legs except hind femora, antennae except at tip, light brown to orange; genal cones lighter colored at apex than at base. . . . Wings transparent, clear or often with a slight yellowish tinge, especially in the distal cells; with a conspicuous black spot at tip of clavus. . . ." WINTER FORM. "General color very dark reddish brown to black; markings black; areas noted in summer form as lighter are correspondingly a little lighter here, but antennae mostly dark from base to tip; wings darker on basal portion, apically clear, veins black and very conspicuous, black claval spot more pronounced."—Crawford.

STRUCTURE: Vertex a little over  $\frac{1}{2}$  as long as wide, discal impressions and medial suture very prominent, especially anteriorly. Genal processes  $\frac{4}{7}$  as long as vertex, robust, contiguous basally, sharp apically. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Hind tibia with small basal spur. Forewings slightly over twice as long as wide, four diffuse radular areas on margin; venation typical, pterostigma large.

GENITALIA: Male proctiger short, slender, curved caudad. Forceps almost as long as proctiger, narrowed from base to acute black apices. Female genital segment shorter than rest of abdomen, stout, dorsal valve slightly longer than ventral, blunt.

\* From *pyrus* -i, L. f. noun—pear + *cola*, L.—inhabitant.

This, the pear psylla, was introduced from Europe early in the 19th century. It is of great importance as a pest on its host plant, *Pyrus communis*, the common pear. Since its introduction into the New England states, it has spread north, south, and west, having been recorded from Nova Scotia, Maine, Connecticut, Massachusetts, New York, New Jersey, Maryland, Virginia, North Carolina, Ohio, Illinois, Michigan, Ontario, British Columbia (?), and California (?). Recently, it has made its appearance in the Pacific Northwest, in the Spokane, Washington, area. Besides North America it is known to occur in most of Europe, and northern and central Asia, including Japan.

Lintner (1893) discusses it in detail, gives figures, life history, damage, and a complete history of its occurrence in North America to that date, including a bibliography.

A brief life history taken from the sources cited above is as follows: The overwintering stage is the adult. Copulation and egg-laying begin in early spring (April in New York). Approximately a month is required for the insects to reach maturity. Breeding continues throughout the season, there being several generations per year.

Due to its economic importance, this psyllid has been discussed at great length and in considerable detail in various bulletins and other economic entomological literature. A great deal of research has been done on control work, especially in New York state. This literature is too voluminous to be cited here but is all listed in the Indices of American Economic Entomology.

### *Psylla americana*\* Crawford

(Figs. 49, 91)

1914 *Psylla americana* Crawford, U. S. Nat. Mus., Bull. 85:138, 147.

1917 *Psyllia americana* Van Duzee, Cat. Hemip. N. Am. 808.

1932 *Psyllia americana* Klyver, Ent. News 43:71.

1938 *Psyllia americana* Strickland, Can. Ent. 70:204.

Length to tip of folded wings 3 to 3.75 mm.

COLOR: General color red to reddish brown. Vertex usually whitish medially. Genal processes light basally, dark toward apex. Pronotum black on cephalic half, remainder white. More or less distinct white margin on lateral and posterior margins of prescutum. Variable white lines on scutum and scutellum. Wings hyaline, veins dark, pterostigma dark.

STRUCTURE: Head strongly deflexed. Vertex with deep discal impressions, about  $\frac{2}{3}$  as long as wide, somewhat bulging anteriorly. Genal processes slender, divergent, blunt,  $\frac{2}{3}$  as long as vertex. Antennae about  $1\frac{1}{3}$  times as long as width of head or slightly longer. (I have seen none in which the ratio is as much as 1.5:1). Thorax well arched. Pronotum large, nearly vertical. Hind tibia with small basal spur. Forewings large, about  $2\frac{1}{2}$  times as long as wide; marginal cells large, pterostigma large. Membrane of both fore- and hind wings thickly set with minute setae.

\* Adjectival form of America.



**GENITALIA:** Male genitalia large. Proctiger long, straight, slightly bent caudad apically. Forceps large; in lateral view broad basally, cephalic margin tapered to acute apices; in caudal view slender, almost straight to subacute black apices. Female genital segment as long as rest of abdomen, slender, straight; dorsal valve straight, apical third very slender, apex acute in both lateral and dorsal view, considerably longer than ventral valve; latter acute.

Described from specimens from "Mountains near Claremont, California"—C. F. Baker. These specimens are considered as typical. Many other specimens are at hand from numerous localities in California, from Utah, and Colorado. It is also recorded from Idaho and Nova Scotia. A series of specimens in the United States National Museum from Banff Springs, Alberta, is, I assume, the basis for Crawford's record for that locality. They represent a distinct species, however, which is described below. The host plants of this abundant species are willow (*Salix* spp.). Crawford records the type as in his collection, but there seems to be no specimen so designated.

*Psylla americana curta*\* n. subsp.

(Fig. 92)

Length to tip of folded wings 3 mm.

**COLOR:** Similar to *P. americana*.

**STRUCTURE:** Similar to typical subspecies except antennae slightly longer,  $1\frac{1}{2}$  times as long as width of head.

**GENITALIA:** Male genitalia much smaller, heavily pubescent. Proctiger scarcely longer than forceps, stout, curved caudad. Forceps in lateral view stout, tapered to subacute apices, in caudal view stout, somewhat arched, apices touching. Female genital segment shorter than rest of abdomen, slender; dorsal valve straight, long, apical portion slender, straight to blunt tip; ventral valve much shorter than dorsal, not upturned, straight to acute apex.

Biological evidence may subsequently prove this to be a distinct species, but since no such data are available I am unwilling to give it that status even though it can be distinguished from typical *americana*, the only distinct difference being in the male genitalia. This would appear to be the form Crawford had in mind when he established *P. americana minor*. His designated type for that name, however, is distinct from this form.

Specimens are at hand from Del Mar, San Jose, Berkeley, San Francisco, Monterey, Fieldbrook, Little River, Lompoc, Alameda County, and Los Angeles County, California (some of the latter were collected on *Salix californica*, April, Koebele), and Colorado.

**HOLOTYPE**, male, No. 55172 United States National Museum, Del Mar, California, June 2, 1935, Oman; **ALLOTYPE** same data. Holotype, allotype,

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\* *curtus* -a -um, L. adj.—short.



and paratypes in United States National Museum, paratypes in Snow Collection, University of Kansas, and author's collection.

*Psylla confusa*\* n. sp.

(Figs. 73, 74, 285)

Length to tip of folded wings 3 mm.

This form is very similar to *P. americana curta* except in genital characters. Membrane of forewings without or almost without the minute setae which are so numerous on *americana* and *americana curta*. Antennae somewhat shorter, about  $1\frac{1}{4}$  times as long as the width of the head. Since it is distinguishable, and from the labels on the specimens at hand appears to live upon an entirely different host, it is somewhat doubtfully given specific rank.

GENITALIA: Male genitalia very sparsely pubescent. Proctiger slender,  $1\frac{1}{2}$  times as long as forceps, hooked caudad apically. Forceps broad, flat, twisted toward apices with flat surface caudad, sharply narrowed near apices leaving a large blunt apical tooth, caudal margins sinuate. Female genital segment shorter than *curta*; dorsal valve concave dorsally, apical portion slender, tip blunt, slightly upturned; ventral valve shorter than dorsal, sharply upturned.

Described from specimens from Utah, Nevada, and Arizona, all collected in March and April; several bear host plant labels which with one exception are *Covillea tridentata* or *C. tridentata* (creosote bush).

HOLOTYPE, male, No. 55173 United States National Museum, St. George, Utah, March 9, 1934, E. W. Davis, *C. tridentata*; ALLOTYPE and 11 PARATYPES same data. Other PARATYPES as follows: 9 Hoytsville, Utah, April 17, 1912, V. L. Wildermuth; 3 Riverside, Nevada, Mar. 8, 1934, E. W. Davis, *C. tridentata*; 2 Littlefield, Arizona, April 28, 1931, E. W. Davis, *Covillea tridentata*; 1 same locality and collector Mar. 27, 1931, *Pluchea sericea*; 1 Arizona, C. F. Baker.

Holotype, allotype, and paratypes in United States National Museum. Paratypes in author's collection.

*Psylla parallela*† Crawford

(Fig. 75)

1914 *Psylla parallela* Crawford, U. S. Nat. Mus., Bull. 85:137, 141.

1917 *Psyllia parallela* Van Duzee, Cat. Hemip. N. Am. 805.

1932 *Psyllia parallela* Klyver, Pan-Pac. Ent. 8:16.

Length to tip of folded wings 3 mm.

COLOR: Yellowish green (?). I have seen only the type specimens which are rather old and apparently faded to a yellowish shade.

STRUCTURE: Head small, strongly deflexed. Vertex  $\frac{1}{2}$  as long as wide with deep discal impressions, bulging in front each side of median suture.

\* *confusus* -a -um, L. adj.—confused.

† *parallelus* -a -um L. adj.—parallel, application obscure.

Genal processes small, slender, rather sharp,  $\frac{2}{3}$  as long as vertex. Antennae short, about  $1\frac{1}{4}$  times as long as width of head. Thorax well arched. Pronotum almost vertical. Hind tibia with small basal spur. Forewings of moderate size, almost  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma large, yellow.

GENITALIA: Male proctiger straight, swollen from base to middle then tapered to broad, rounded apex. Forceps short; in lateral view narrow basally, caudal margin slightly excavate, cephalic margin strongly bulged midway then narrowed to near apices, apically produced both cephalad and caudad as a black tooth, general appearance T-shaped; in caudal view stout basally, bowed outward, apical third strongly narrowed, bent mesad, apices black, truncate. "Female genital segment as long as rest of abdomen, slender, dorsal valve longer than ventral."—Crawford.

I have seen only the type specimens, which are from Nevada County, California, Castle Rock, collected by Koebele in September. Klyver records it from Washington and British Columbia. I am rather doubtful of these records; the specimens referred to are probably *P. minor*, the male genitalia of which resemble those of *P. parallela*. The former is very abundant in the Pacific Northwest.

Host entirely unknown.

TYPES, 2 males (on same pin), No. 18106 United States National Museum, with data given above, have been examined.

### *Psylla minor*\* Crawford

(Fig. 76, 77)

1914 *Psylla americana minor* Crawford, U. S. Nat. Mus., Bull. 85:138, 147.

1914 *Psylla rufula* Crawford, U. S. Nat. Mus., Bull. 85:148.

1917 *Psyllia americana minor* Van Duzee, Cat. Hemip. N. Am. 808.

1932 *Psyllia americana minor* Klyver, Ent. News 43:72.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: General color dark brown, abdomen black. Some white on vertex and thoracic dorsum. Females lighter than males. Wings whitish. Veins black. Pterostigma fumate.

STRUCTURE: Head strongly deflexed. Vertex about as long as wide, discal impressions prominent. Genal processes slender, slightly divergent, slightly over  $\frac{2}{3}$  as long as vertex. Antennae  $1\frac{1}{3}$  to  $1\frac{1}{2}$  times as long as width of head. Thorax well arched. A blunt tooth at base of hind tibia. Forewings large, enlarged toward apices,  $2\frac{1}{4}$  times as long as wide; marginal cells large, cubital larger than medial, pterostigma of moderate width, very long. Hind wings very long. Membrane of both fore- and hind wings thickly set with minute setae.

GENITALIA: Male genitalia large, very pubescent. Proctiger stout, curved cephalad, then strongly caudad to truncate apex. Forceps almost as long as proctiger; in lateral view broad at base, narrowed, swollen midway, converging slightly to near apices then enlarged, apices roundly

\* *minor* -us, L. adj. (comp. of *parvus*)—smaller.

truncate; in caudal view large, swollen basally, apical third narrowed and straight to truncate apices. Female genital segment somewhat shorter than rest of abdomen; dorsal valve much longer than ventral, straight, apical half slender, apex blunt; ventral valve nearly straight to acute black apex.

Described from many specimens from numerous localities in Oregon, Washington, and Colorado. A series received from Mr. R. L. Post of the Oregon State College, collected in Salem, Oregon, was taken on "pussy willow" and was injuring the plants. This series was erroneously determined as *Psylla parallela* Crawford, a closely related or at least similar species. Other specimens bear labels "willow blossom," "willow bloom," "willow," etc. Crawford records specimens on *Salix lasiolepis*, *Salix californica*, and *Salix* sp. The hosts are apparently several species of willow (*Salix* spp.). Crawford records it from several localities in California. I believe these records refer to *P. americana curta*, a form which he seems to have had confused with *minor*. The type specimen, a male, on which the above description is based, is not, in my opinion, conspecific with *americana*. It is, however, the same species as Crawford's *americana flava*, the latter being but a color variety of *minor*.

TYPE, male, No. 18109 United States National Museum, Colorado, "from Gillette Collection, 1894."

Type examined.

*Psylla minor* var. *flava*\* Crawford n. comb.

1914 *Psylla americana flava* Crawford, U. S. Nat. Mus., Bull. 85:138, 148.

1914 *Psylla americana longipennis* Crawford, U. S. Nat. Mus., Bull. 85:148.

1917 *Psyllia americana flava* Van Duzee, Cat. Hemip. N. Am. 808.

1938 *Psyllia americana flava* Strickland, Can. Ent. 70:204.

This form is a color variety of *P. minor*. It is in general yellow instead of reddish brown or black. Specimens are at hand from Vancouver, B.C.; Oregon (Koebele); California; Utah Lake, Alta, and Park City, Utah, and Colorado.

TYPE, No. 18110 United States National Museum, is a somewhat teneral female from Victoria, Vancouver, Hubbard and Schwarz.

Type examined.

*Psylla usitata*† n. sp.

(Figs. 78, 79, 79a, 286)

Length to tip of folded wings 3 mm.

COLOR: General color yellow. Wings whitish; forewings more or less fumate apically. Antennae dark apically.

STRUCTURE: Head strongly deflexed. Vertex slightly impressed discally,  $\frac{1}{2}$  as long as wide, bulging anteriorly, posterior margin nearly straight. Genal processes cone-shaped, blunt, divergent,  $\frac{2}{3}$  as long as

\* *flavus* -a -um, L. adj.—yellow.

† *usitatus* -a -um, L. adj.—ordinary.

vertex. Antennae somewhat over  $1\frac{2}{3}$  times as long as width of head. Thorax moderately arched. Hind tibia with small basal tubercle. Forewings about  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma of moderate size. Membrane of both fore- and hind wings thickly set with minute setae.

**GENITALIA:** Male proctiger very short, straight on caudal margin, slightly convex on cephalic margin. Forceps very pubescent, nearly as long as proctiger; in lateral view broad, margins parallel to broadly notched apices; in caudal view broad, evenly arched, notched, medial lobes produced as heavy, subacute black teeth; in dorsal view apices deeply notched, anterior lobe large, blunt, caudal lobe produced anteriorly as a black tooth, narrow basally, enlarged and sharply truncate. Female genital segment shorter than rest of abdomen, dorsal valve concave dorsally, apex upturned, acute; ventral valve shorter than dorsal, upturned, acute.

**HOLOTYPE**, male, No. 55174 United States National Museum, **ALLOTYPE**, female, 9 male and 6 female **PARATYPES**, Deborgia, Montana, July 9, 1935, P. W. Oman.

Holotype, allotype, and paratypes in United States National Museum, paratypes in author's collection.

*Psylla latiforceps*\* n. sp.

(Figs. 80, 81, 287)

Length to tip of folded wings 3 to 3.5 mm.

**COLOR:** General color greenish yellow to yellow. Wings hyaline. Distal half of antennae, apical tarsal segments, and wing veins apically, dark. Sometimes a fumate spot in apex of clavus.

**STRUCTURE:** Head small, vertical. Vertex  $\frac{1}{2}$  as long as wide, with deep discal impressions, bulging anteriorly. Genal processes slender, subacute, strongly divergent,  $\frac{2}{3}$  as long as vertex. Antennae rather thick, somewhat less than  $1\frac{1}{3}$  times as long as width of head. Thorax strongly arched. Pronotum nearly vertical. Hind tibia with very small basal spur. Wings very large,  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma moderately large.

**GENITALIA:** Male proctiger in lateral view broad, parallel-sided, straight or flexed caudad apically, longer than forceps. Forceps in lateral view moderately broad basally, suddenly enlarged on cephalic margin then parallel-sided to apices, apices very heavily sclerotized, obliquely truncate, produced caudad as a short heavy tooth; in caudal view broad, very slightly arched; in dorsal view apices are very heavy, long, produced caudad as a small mesal tooth. Female genital segment longer than rest of abdomen; dorsal valve straight, apex attenuate, slightly downcurved, blunt; ventral valve long, straight, acute.

**HOLOTYPE**, male, **ALLOTYPE**, female, numerous **PARATYPES**, Creede,

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\* From *latus* -a -um, L. adj—broad + *forceps* -cipis, L. m. and f. noun—forceps.

Colorado, July 14, 1940, L. D. Tuthill. Additional PARATYPES: Creede, Colorado, 1936 to 1939, L. D. Tuthill; Redmond, Oregon, April and June, 1939, Schuh and Gray. One teneral pair from Easton, Washington, (Koebele) is perhaps also conspecific.

Holotype, allotype, and paratypes in author's collection. Paratypes in Oregon State College Collection, United States National Museum, and University of Kansas.

The Creede specimens were taken on willow. As many of them are very teneral, and nymphs (presumably of the same species) were taken at the same time, *Salix* sp. is undoubtedly the host.

### *Psylla sinuata*\* Crawford

(Figs 93, 94)

1914 *Psylla sinuata* Crawford, U. S. Nat. Mus., Bull. 85:137, 140.

1914 *Psylla fibulata simulans* Crawford, U. S. Nat. Mus., Bull. 85:140.

1917 *Psyllia sinuata* Van Duzee, Cat. Hemip. N. Am. 805.

1932 *Psyllia sinuata* Klyver, Ent. News 43:71.

1938 *Psyllia sinuata* Strickland, Can. Ent. 70:205.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: Light green to light yellow brown to orange. Segments of antennae black-tipped, distal segments entirely black. Wings slightly whitish.

STRUCTURE: Head small, strongly deflexed, almost perpendicular. Vertex with shallow discal impressions, almost flat, nearly twice as wide as long. Genal processes slender, divergent, blunt, slightly over  $\frac{1}{2}$  as long as vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax scarcely arched. Pronotum strongly descending. Hind tibia with very slight tubercle at base. Forewings about  $2\frac{1}{2}$  times as long as wide; Rs sinuate, marginal cells somewhat elongate, pterostigma of medium size. Membrane of both fore- and hind wings thickly set with minute setae.

GENITALIA: Male genitalia very large with heavy, fine pubescence. Proctiger broad, slightly curved caudad, tapered to sharp apex. Forceps in lateral view evenly curved caudad on anterior margin, caudal margin sinuate to black, blunt apices; in caudal view broad, well arched, produced midway as a large mesal lobe, apices black, heavy. Female genital segment longer than rest of abdomen, very thickly set apically with minute setae; dorsal valve much longer than ventral, straight, flattened and rounded apically; ventral valve strongly upcurved, flattened, acute.

Described from numerous specimens taken on willow at 11,000 feet near Creede, Colorado. Other specimens are at hand from Colorado (C. F. Baker); Ungva Bay, H. B. T., L. M. Turner; Birch River, and Swan River, Manitoba, R. H. Beamer; Itasca Park, Minnesota. It is also recorded from Idaho and Alberta. Strickland records white spruce (*Picea alba*) as a definite host.

TYPE, male, No. 18105 United States National Museum.

Type examined.

\* *sinuatus*, L. (p. part. of *sinuo*)—wavy.



*Psylla fibulata*\* Crawford

(Figs. 95, 96)

1914 *Psylla fibulata* Crawford, U. S. Nat. Mus., Bull. 85:137, 140.1917 *Psyllia fibulata* Van Duzee, Cat. Hemip. N. Am. 805.1932 *Psyllia fibulata* Klyver, Ent. News 43:71.1938 *Psylla fibulata* (?) Strickland, Can. Ent. 70:204.

Length to tip of folded wings 2.5 to 3 mm.

COLOR: General color whitish green to yellow. Antennae dark apically. Wings more or less whitish.

STRUCTURE: Head small, strongly deflexed. Vertex with shallow discal impressions, roundly bulging anteriorly, slightly over  $\frac{1}{2}$  as long as wide. Genal processes small, slender, divergent, blunt, slightly over  $\frac{1}{2}$  as long as vertex. Antennae small,  $1\frac{1}{3}$  times as long as width of head. Thorax very strongly arched. Legs small, hind tibia with very small tubercle at base. Fore- and hind wings large, greatly exceeding abdomen, membranes thickly set with minute setae. Forewings slightly over  $2\frac{1}{2}$  times as long as wide; venation typical, pterostigma large, long.

GENITALIA: Male proctiger long, slightly curved caudad. Forceps produced caudad basally as rounded lobes, caudal margins then excavate to apices, anterior margins almost straight, apices black, subacute. Female genital segment stout, black-tipped, longer than rest of abdomen; dorsal valve straight, subacute, broad, somewhat "shovel-shaped"; ventral valve shorter, broad, upcurved.

Described from numerous males and females taken at Creede, Colorado, July 14, 1940, on willow (*Salix* sp.); many of the specimens are very teneral and were accompanied by nymphs presumably of the same species. Other specimens at hand bear the label, "Colorado, C. F. Baker."

TYPE, female, No. 18104 United States National Museum.

Type examined.

*Psylla propria*† n. sp.

(Figs. 84, 85)

Length to tip of folded wings 4 mm.

COLOR: General color chocolate brown. Lighter to white along medial suture of vertex, base of genal processes, proximal portion of antennae, caudal half of pronotum, caudal margin of prescutum, longitudinal lines on scutum, margins of scutellum, tibiae, tarsi and margins of abdominal sclerites. Wings hyaline; pterostigma brown.

STRUCTURE: Head strongly deflexed. Vertex about  $\frac{1}{2}$  as long as wide, prominently impressed discally. Genal processes  $\frac{2}{3}$  as long as vertex, not divergent, parallel to plane of vertex, blunt. Antennae  $1\frac{1}{3}$  times as long as width of head. Thorax well arched. Pronotum nearly vertical. Hind tibia with two small basal tubercles. Forewings  $2\frac{1}{2}$  times

\* *fibulatus*, L. (p. part. of *fibulo*—to fasten together)—significance obscure.† *proprius* -a -um, L. adj.—peculiar.



as long as wide; marginal cells large, pterostigma large; four radular areas on apical margin. Membrane of both fore- and hind wings set with minute setae.

**GENITALIA:** Male genitalia large. Proctiger very long, twice as long as forceps; in lateral view slender, straight to near apex then sharply flexed caudad. Forceps stout; in lateral view narrow basally, very much enlarged and bent cephalad then narrowed, apices truncate, black, produced on mesal margin; caudo-mesal margins produced caudad basally; in caudal view very broad, straight, lateral margins incurved apically to subacute apices; median portion of each forcep excavate caudally leaving margins raised as sharp ridges, mesal margin produced basally and apically, lateral margin produced above mid-point. Female genital segment as long as rest of abdomen, slender; dorsal valve straight, slender from base, apex blunt; ventral valve shorter than dorsal, slightly concave ventrally in proximal half, abruptly turned dorsad to acute apex.

Described from 8 males and 13 females from Colorado, C. F. Baker, and 1 male from Milford, Utah, April 24, 1934, E. W. Davis. The latter specimen bears a label *C. repand*.

Holotype, allotype, and paratypes in United States National Museum, paratypes in author's collection.

HOLOTYPE, male, No. 55176 United States National Museum, Colorado.

*Psylla uncata*\* n. sp.

(Figs. 82, 83, 288)

Length to tip of folded wings 3.5 mm.

**COLOR:** General color reddish brown. Abdomen and venter darker. Thorax with more-or-less distinct light stripes. Vertex light-margined. Wings whitish.

**STRUCTURE:** Head strongly deflexed. Vertex  $\frac{1}{2}$  as long as wide, discal impressions very broad, deep. Genal processes small, cone-shaped, subacute, less than  $\frac{2}{3}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Vertex and thorax punctate. Thorax moderately arched. Pronotum descending but not vertical. Hind tibia with very small basal spur. Membrane of both fore- and hind wings thickly set with minute setae. Forewings over twice as long as wide; venation typical, pterostigma prominent, dark.

**GENITALIA:** Male proctiger slightly longer than forceps, almost parallel margined, slightly and evenly curved caudad. Forceps heavily pubescent; in lateral view broad basally, caudal margin almost straight, cephalic margin produced in basal half then strongly excavate, apices extending cephalad as a black hook; in caudal view stout, slightly and evenly arched to truncate apices. Female genital segment shorter than rest of abdomen; dorsal valve slightly upcurved, apex blunt; ventral valve but slightly shorter than dorsal, ventral margin evenly upcurved to acute apex, dorsal margin produced dorsad as a large broad lobe midway.

\* *uncatus* -a -um, L. adj.—hooked.

Described from two males and six females from Banff Springs, Alberta, Hubbard and Schwarz. Five other females bearing the same data are probably the same species but are atypical in structure of genitalia.

Holotype, allotype, and paratypes in United States National Museum, paratypes in author's collection.

HOLOTYPE, male, No. 55175 United States National Museum.

*Psylla alaskensis*\* Ashmead

(Figs. 65, 66, 282)

1904 *Psylla alaskensis* Ashmead, Harriman Alaska Exped. 8:137.

1913 *Psylla alaskensis* Aulmann, Psy. Cat. 8.

1914 *Psylla alaskensis* Crawford, U. S. Nat. Mus., Bull. 85:138, 149.

1917 *Psyllia alaskensis* Van Duzee, Cat. Hemip. N. Am. 809.

1938 *Arytaina fuscata* Caldwell, Ann. Ent. Soc. Am. 31:443.

Length to tip of folded wings 2.75 to 3 mm.

COLOR: General color orange to reddish brown, faint longitudinal stripes on scutum. Forewings with veins dark, prominent, membrane more or less fumate, more heavily apically, sometimes with a white bloom.

STRUCTURE: Vertex  $\frac{2}{3}$  as long as wide, with two discal foveae, strongly bulging anteriorly. Genal processes cone-shaped, blunt, about  $\frac{3}{4}$  as long as vertex. Antennae short, pubescent, about  $1\frac{1}{3}$  times as long as width of head. Thorax quite flat for this genus. Hind tibia with slight tubercle at base. Forewings long and slender, over  $2\frac{1}{2}$  times as long as wide, tapering apically to narrowly rounded apices; Rs reaching almost to apex, cells elongate, narrow, cubital larger than medial, pterostigma very long, narrow.

GENITALIA: Male subgenital plate large, globose. Proctiger broad, short; in lateral view broad and straight. Forceps in caudal view stout, moderately arched to acute, black apices; in lateral view broad basally, cephalic margin excavate about midway to apex, then strongly narrowed to black apex, apically produced anteriorly as a rather sharp tooth, caudal margin straight to near apex then extending caudad. Female genital segment as long as or longer than rest of abdomen, both valves broad, somewhat shovel-like, dorsal valve straight, much longer than ventral, latter stout, black-tipped.

Described from numerous specimens from Alaska, Colorado, and one specimen bearing the label, "Ks. 2138, C. F. Baker." Ashmead's description of the color seems to have been based on rather teneral specimens. His illustration of the male genitalia is of very little value as the tips of the forceps are not shown.

The type is apparently lost or destroyed. There remain in the United States National Museum but two specimens of the original series, one male from Fox Point and one female from Seldovia, Alaska. The male is here designated as neotype.

\* Adjectival form of Alaska.

In Colorado this species has been taken on *Salix* sp. at altitudes of about 11,000 feet.

A paratype of Caldwell's *Arytaina fuscata* in the collection of the University of Minnesota has been examined, and it is undoubtedly conspecific with the Alaskan specimens at hand. This adds Manitoba to the known range of the species. Numerous additional specimens from Churchill, Manitoba, differ from the type in having broad, short forewings and blunter genal processes.

TYPE, male, No. 6274 United States National Museum, Fox Point, Alaska.

Type examined.

Two species of *Psylla* have been described from Greenland by Sulc, *Psylla groenlandica* (Ann. Hist-Nat. Mus. Nat. Hungarici 11:424, 1913) and *Psylla septentrionalis* (Ann. Mag. Nat. Hist. 4 (ser. 11):78, 1939). Both of these forms show affinities to *alaskensis*. The Churchill, Manitoba, specimens referred to above appear to be somewhat intermediate between *alaskensis* and *groenlandica*, but until more extensive collections are made in this northern area no conclusions as to the exact relationship of these forms can be drawn.

*Psylla phoradendri*\* Tuthill

(Figs. 50, 51, 276)

1939 *Psylla phorodendrae* Tuthill, Ia. St. Coll. Jour. Sci. 13:186.

Length to tip of folded wings 3 mm.

COLOR: Green, forewings olive green.

STRUCTURE: Head very broad. Genal processes short, not as long as broad, rather blunt. Antennae  $1\frac{1}{2}$  times as long as width of head. Eyes borne on prominent stalklike area of head. Thorax very broad. Wings twice as long as wide; cubital cell larger than medial, latter slender, Rs straight to near apex, sharply turned toward costa, pterostigma large.

GENITALIA: Male proctiger narrow in lateral view, straight. Forceps very slender in lateral view, base somewhat enlarged, remainder bent forward, apices blunt, postero-apical margins sharp, black-margined; in caudal view arched, apices touching, a large mesally projecting, black-tipped tooth near base. Apical portion of aedeagus very much enlarged, in dorsal view notched apically, large wing-shaped lateral lobes, two slender, retrorse, medial processes extending caudad. Female genital segment short, about  $\frac{1}{2}$  as long as remainder of abdomen; dorsal valve elongate hood-shaped; ventral valve very short with a large median, transparent, truncate tooth.

In addition to the type specimens from Los Angeles County, California, and Huachuca Mountains, Arizona, specimens are at hand from the Santa Rita Mountains, Arizona. Additional specimens from the Huachuca Mountains bear the host plant label *Phoradendron tomentosum* Olivar.

\* Genitive of *Phoradendron*—the generic name of the host plant.

The original spelling of the name as *phorodendrae* was an error in transcription and is here amended to *phoradendri*.

TYPE, female, Huachuca Mountains, Arizona, in the Snow Collection, University of Kansas.

*Psylla annulata*\* Fitch

(Figs. 97, 98)

- 1851 *Psylla annulata* Fitch, 4th Rept. N. Y. Sta. Mus. 64.  
 1885 *Psylla annulata* Riley, Proc. Biol. Soc. Wash. 2:70.  
 1910 *Psylla annulata* Smith, Ins. N. J. 109.  
 1912 *Psylla annulata* Patch, Me. Agr. Exp. Sta., Bull. 202:219.  
 1913 *Psylla annulata* Aulmann, Psy. Cat. 10.  
 1914 *Psylla annulata* Crawford, U. S. Nat. Mus., Bull. 85:152.  
 1917 *Psylla annulata* Van Duzee, Cat. Hemip. N. Am. 809.  
 1918 *Psylla annulata* McAtee, Ent. News 29:223.  
 1938 *Psylla annulata* Caldwell, Ohio Biol. Surv., Bull. 34:264.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: General color light yellow, abdomen often green. Antennae with dark annulus apically on each segment. Wings whitish.

STRUCTURE: Head unusually wide. Vertex short, slightly impressed discally, abrupt anteriorly. Median ocellus far below plane of vertex. Eyes borne on very prominent stalklike areas of head, definitely separated from raised portion of vertex. Genal processes slender, cone-shaped, divergent, blunt, as long as vertex, longer than median length of vertex. Antennae twice as long as vertex. Thorax scarcely arched. Hind tibia with short basal spur. Forewings broad,  $2\frac{1}{2}$  times as long as wide, membrane minutely setate; veins biseriately set with very fine setae; venation typical, pterostigma very broad.

GENITALIA: Male genitalia small. Proctiger short, almost straight. Forceps in lateral view straight; in caudal view straight basally then bowed out and arched to sharp black apices. Female genital segment short, shorter than rest of abdomen; dorsal valve slightly longer than ventral, almost straight to rounded apex; ventral valve strongly upcurved.

Described from specimens from the following localities: New York, Massachusetts, New Hampshire, Connecticut, Maine, Michigan, and Iowa. Caldwell records it from Ohio and McAtee from Maryland.

The host is *Acer saccharum* Marsh.

*Psylla negundinis*† Mally

- 1895 *Psylla negundinis* Mally, Proc. Ia. Acad. Sci. 2:155-159.  
 1912 *Psylla negundinis* Patch, Me. Agr. Exp. Sta., Bull. 202:220.  
 1913 *Psylla negundinis* Aulmann, Psy. Cat. 20.  
 1914 *Psylla negundinis* Crawford, U. S. Nat. Mus., Bull. 85:152.  
 1917 *Psylla negundinis* Van Duzee, Cat. Hemip. N. Am. 809.  
 1938 *Psylla negundinis* Caldwell, Ohio Biol. Surv., Bull. 34:265.  
 1938 *Psylla negundinis* Strickland, Can. Ent. 70:205.

Length to tip of folded wings 3.5 to 4 mm.

\* *annulatus* -a -um, L. adj.—ringed.

† Genitive of *Negundo*, the host plant.

Very similar to *annulata* from which it is distinguished chiefly by the lack of annulations on the antennae. Color uniformly green to yellow, except tip of antenna black. The host plant is box elder, *Acer negundo*.

Specimens are at hand from Iowa, Nebraska, Kansas, Minnesota, North Dakota, Manitoba, Colorado, Utah, and Arizona. It is also recorded from Wisconsin, New Mexico, Ohio, and Alberta (Strickland, on *Negundo interius*).

The life cycle is recorded by Mally as follows:

"The eggs are deposited in autumn just as soon as the leaves begin to fall. They are inserted closely around the edge of the buds, but are attached to the twig, so in case the bud is broken off the eggs still remain in place. They hatch in early spring, enter the opening buds and feed by sucking the juices from the young tissue. When the leaves are large and have a long petiole, the young larva may be found anywhere on the under side of the leaf, on the petiole, or more preferably at the axil of the leaf, with head downward, i.e., toward the stem, and crowded as far down as possible for protection. In this position they may be observed for hours, sitting very quietly, only moving the abdomen laterally or vertically occasionally so as to remove the white mass of excreta and the cottony wax secretion. They pass through five stages and emerge as adults about the middle of May or the first of June. The adults live on the trees during the summer months, feeding on the plant juices, pairing, and maturing the eggs till autumn. When the leaves begin to fall and expose the buds, the female begins depositing the little white glistening eggs around the edges of the buds, and their life cycle is complete."

TYPE, male, in the collection of Iowa State College.

### *Psylla ribis*\* Patch

1912 *Psylla ribis* Patch, Me. Agr. Exp. Sta., Bull. 202:222.

1914 *Psylla ribis* Crawford. U. S. Nat. Mus., Bull. 85:148.

1917 *Psyllia ribis* Van Duzee, Cat. Hemip. N. Am. 809.

I am unable to place this species as none of Patch's specimens are available. Were it not for the fact that Crawford states definitely that it is not the same as *ribesiae* (a statement based on study of Miss Patch's specimens), I would believe it to be synonymous with that species. Her pictures and his description do not agree perfectly, however, so it remains a mystery until the type specimens are found and its identity established.

### *Psylla arctica*† (Walker)

1852 *Aphalara arctica* Walker, List. Homop. Br. Mus., pt. IV:931-932.

1882 *Psylla arctica* Scott, Trans. Ent. Soc. London 1882:459.

1885 *Psylla arctica* Riley, Proc. Biol. Soc. Wash. 2:69.

1900 *Psylla arctica* Schwarz, Proc. Wash. Acad. Sci. 2:540.

1913 *Psylla arctica* Aulmann, Psy. Cat. 10.

1917 *Psyllia arctica* Van Duzee, Cat. Hemip. N. Am. 808.

\* Genitive of *Ribes*—the generic name of its hosts.

† *arcticus* -a -um, l. adj.—arctic.



Described from three females from St. Martins Falls, Albany River, Hudson Bay. Scott figures the head, wing, and genital segment. This species seems to belong in the *americana* complex. Just which one of the forms in this group it may be I have no idea.

Types in British Museum.

### Genus *Arytaina*\* Förster

- 1804 *Psylla* Latreille [*pro parte*], Hist. Nat. Crust. Ins. 12:377-382.
- 1848 *Arytaina* Förster, Verh. natur. Ver. preuss. Rhein. 5:67.
- 1872 *Arytaina* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:380, 404.
- 1876 *Arytaena* Scott, Trans. Ent. Soc. London 1876:528.
- [non] *Arytaena* Oken, 1817.
- 1877 *Ataenia* Thomson, Opusc. Ent. 8:828 [as a subgenus of *Chermes*].
- 1879 *Arytaena* Löw, Verh. zool.-bot. Ges. Wien 28:586.
- 1896 *Arytaena* Edwards, Hemip.-Homop. Br. Is. 250.
- 1911 *Psyllopa* Crawford, Pom. Coll. Jour. Ent. 3:628; *ibid.* 4:684, 1912 [note].
- 1912 *Arytaina* Oshanin, Kat. paläa. Hemip. 128.
- 1913 *Arytaena* Aulmann, Psy. Cat. 32.
- 1914 *Arytaina* Crawford, U. S. Nat. Mus., Bull. 85:122.
- 1914 *Euglyptoneura* Crawford, U. S. Nat. Mus., Bull. 85:125.
- 1914 *Brachypsylla* Crawford (*pro parte*), U. S. Nat. Mus., Bull. 85:129.
- 1914 *Amblyrhina* Crawford, U. S. Nat. Mus., Bull. 85:130.
- 1917 *Arytaina* Van Duzee, Cat. Hemip. N. Am. 803.
- 1926 *Peripsyllopsis* Enderlein, Ent. Mitt. 15:399.

Head more or less deflexed, narrower to distinctly wider than thorax. Genae produced as rounded, usually short processes, strongly depressed from but parallel to plane of vertex. Antennae moderately long. Thorax arched. Pronotum large, flat, ending in a knoblike swelling laterally. Propleurites equal at juncture with pronotum. Forewings often narrowly rounded apically, usually more or less maculate or fumate, sometimes rugose and somewhat coriaceous, pterostigma present or wanting. Metatibia sometimes with basal spur. Basal segment of metatarsus with two black clawlike spines.

**HAPLOTYPE:** *Arytaina genistae* (Latreille).

Originally separated from *Psylla* by the lack of a pterostigma in the forewing, a character which is not of sufficient importance in itself to warrant such a distinction. Both Förster and Scott separated the genera on this basis, then with no explanation proceeded to describe species of *Psylla* such as *buxi* in which there is no pterostigma. Thomson used the lack of a pterostigma and the apically narrowed forewing of *genistae* as the chief distinguishing characters. In my opinion the principal characters of this group are those stressed by Crawford, namely, the shape of the prothoracic pleurites, the shape and position of the genal processes, the large flattened pronotum, and the often more-or-less coriaceous forewings.

Enderlein (1926) refers all the North American species back to *Psylla*—apparently without having seen any of them.

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\* *Arytaena* -ae, G. f. noun—ladle or dipper (so named because the genus has a sucker or proboscis).



The Committee on Nomenclature, Division of Insect Identification of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, headed by C. F. W. Muesebeck, has recently expressed an opinion concerning the valid name for this genus. It is the conclusion of this committee that the original spelling of the name, *Arytaina*, must be preserved even though Förster should have transcribed the name from the Greek as *Arytaena* (Appendix F of the International Rules). This opinion is in accord with opinion 125 of the International Commission.

### Key to the Species of *Arytaina*

1. Forewings conspicuously maculate, spotted or entirely dark.....2.  
Forewings not conspicuously maculate, often more or less evenly fumate....7.
2. ( 1) Forewings with prominent pterostigma.....6.  
Forewings with pterostigma almost or entirely obsolete.....3.
3. ( 2) Forewings hyaline except for brown maculae; head broader than thorax  
*genistae* p. 505.  
Forewings otherwise; head narrower than thorax.....4.
4. ( 3) Forewings entirely dark; male forceps bilobate.....*fuscipennis* p. 506.  
Forewings white with brown spots or maculae; male forceps not bilobate....5.
5. ( 4) Body and forewings usually pulverulent; media of forewings not sinuate  
*robusta* p. 506.  
Without white pulverulence; media of forewings sinuate.*robusta sinuata* p. 507.
6. ( 2) Prominently pubescent on head and thorax; forewing white, brown apically; male proctiger without caudal lobes.....*pubescens* p. 508.  
Head and thorax not prominently pubescent; forewing semitransparent; male proctiger with large caudal lobes.....*assimilis* p. 509.
7. ( 1) Genal processes not contiguous basally, very short, rounded.....8.  
Genal processes contiguous, at least basally.....11.
8. ( 7) Pterostigma lacking.....*spartiophila* p. 509.  
Pterostigma prominent.....9.
9. ( 8) Male forceps simple; forewings often somewhat fumate apically  
*ceanothi* p. 510.  
Male forceps with a large anterior lobe and a shorter caudal one; forewings entirely clear or whitish.....10.
10. ( 9) Antennae as long as width of head; genae produced as blunt lobate processes visible in dorsal view of head.....*amorphae* p. 511.  
Antennae  $1\frac{1}{4}$  times as long as width of head; genae not visible in dorsal view of head.....*pallida* p. 512.
11. ( 7) Female genital segment enlarged basally, slender, styliform apically  
*aculeata* p. 513.  
Female genital segment not styliform.....12.
12. (11) Male forceps deeply bifurcate; proctiger small; female genital segment very short, much shorter than abdomen.....*chelifera* p. 514.  
Male forceps simple; proctiger very large; female genital segment very large, stout, longer than rest of abdomen.....13.
13. (12) Forewings narrowed apically, pterostigma prominent.....*minuta* p. 514.  
Forewings broadly rounded, pterostigma obsolete.....*insolita* p. 515.

*Arytaina genistae*\* (Latreille)

(Figs. 99, 100, 101, 250)

- 1804 *Psylla genistae* Latreille, Hist. Nat. Crust. Ins. 12:382.  
 1835 *Psylla ulicis* Curtis, Brit. Ent. 12:565.  
 1841 *Psylla spartii* Hartig, Germ. Zeitschr. Ent. 3:375.  
 1848 *Arytaina spartii* Förster, Verh. natur. Ver. preuss. Rhein. 5:69.  
 1861 *Psylla spartii* Flor, Bull. Soc. Imp. Nat. Moscou 34: 335, 338, 347, 351, 358.  
 1872 *Arytaina spartii* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:405.  
 1876 *Arytaena ulicis* Scott, Trans. Ent. Soc. London 1876:529.  
 1877 *Chermes (Ataenia) genistae* Thomson, Opusc. Ent. 8:828.  
 1879 *Arytaena genistae* Löw, Verh. zool.-bot. Ges. Wien 28:597.  
 1908 *Arytaena genistae* Oshanin, Verz. palae. Hemip. 2:366.  
 1911 *Psyllopa magna* Crawford, Pom. Coll. Jour. Ent. 3:628.  
 1912 *Arytaena genistae* Oshanin, Kat. palae. Hemip. 128.  
 1913 *Arytaena genistae* Aulmann, Psy. Cat. 32.  
 1914 *Arytaina genistae* Crawford, U. S. Nat. Mus., Bull. 85:125.  
 1917 *Arytaina genistae* Van Duzee, Cat. Hemip. N. Am. 803.  
 1921 *Arytaena genistae* Enderlein, Zool. Anz. 52:120.  
 1935 *Arytaena genistae* Haupt, Tierw. Mittel. 4, 3:241.

Length to tip of folded wings 3 to 4 mm.

COLOR: General color light green to dark brown. More-or-less distinctly striped on dorsum. Forewings with a brown macula between Rs and M, another along posterior margin, following Cu nearly to base of wing.

STRUCTURE: Head large, deflexed, broader than thorax. Vertex nearly plane, over  $\frac{1}{2}$  as long as wide, discal impressions slight, anterior margin strongly produced each side of median line as small tubercle, laterally rounded down to genal processes. Eyes very large, protruding, appearing slightly stalked. Genal processes large, heavy, rounded apically, nearly parallel to plane of vertex, not contiguous basally,  $\frac{1}{2}$  as long as vertex. Antennae slightly over twice as long as width of head. Thorax broad, moderately arched. Pronotum nearly flat, long. Forewings long, narrowly rounded apically,  $2\frac{3}{4}$  times as long as wide; Rs long, slightly sinuate, medial cell larger than cubital, pterostigma lacking. Hind tibia with basal spur.

GENITALIA: Male protiger short, stout, curved caudad apically. Forceps as long as protiger, stout; in lateral view bent caudad midway, truncate apically; in caudal view slender, nearly straight to black, bifurcate apices; in dorsal view black-margined, deeply emarginate, caudal tooth stout, sharp, anterior tooth longer, obliquely truncate. Female genital segment longer than rest of abdomen, stout; dorsal valve straight to blunt, slightly upturned apex; ventral valve shorter than dorsal, upturned, acute.

Described from specimens from Europe, determined as *A. genistae* by Franz Löw, in the United States National Museum. Crawford records it from Woods Hole, Massachusetts, on *Spartinum* sp. In Europe its hosts are *Cytisus scoparius* (Scotch broom) and *Ulex europaeus* (gorse) both of which are established in eastern United States. It seems most probable that these same species are the hosts in North America also.

\* Genitive of *genista* -ae, L. f. noun—broom (its host plant).

*Arytaina fuscipennis*\* Crawford

(Figs. 102, 103, 104)

1914 *Arytaina fuscipennis* Crawford, U. S. Nat. Mus., Bull. 85:123, 125.1914 *Euglyptoneura tristis* Crawford, U. S. Nat. Mus., Bull. 85:125.1917 *Arytaina fuscipennis* Van Duzee, Cat. Hemip. N. Am. 803.1932 *Arytaina fuscipennis* Klyver, Ent. News 43:39.

Length to tip of folded wings 2.5 to 2.75 mm.

COLOR: General color brown to black including forewings. Genal processes somewhat lighter, especially in the male.

STRUCTURE: Head scarcely deflexed, narrower than thorax. Vertex with very broad discal impressions, nearly twice as wide as long. Genal processes conical, divergent, from blunt to nearly acute,  $\frac{1}{2}$  to  $\frac{2}{3}$  as long as vertex, pubescent. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax broad, well arched. Pronotum long, straight. Forewings coriaceous, somewhat rugose, twice as long as wide, broadly rounded; veins minutely setate, cubital cell larger than medial, pterostigma very small to obsolete. Hind tibia without basal spur.

GENITALIA: Proctiger of male broad, in lateral view broad basally, converging then slender to apex. Forceps narrow, petiolate basally then produced as two divergent, elongate lobes, medial lobe slender, acute, lateral lobe spatulate. Female genital segment short, about  $\frac{1}{2}$  as long as rest of abdomen; dorsal valve longer than ventral, excavate dorsally to slightly upturned, blunt apex; ventral valve deeply excavate mesally.

Described from numerous males and females from Lapine and Bend, Oregon; two from Los Angeles County, California; one from Palomar Mountain, California, and one from Nevada. Klyver records *Ceanothus papillosus* as a definite host. Crawford records specimens as bearing labels of other species of *Ceanothus*.

TYPE, male, No. 18101 United States National Museum, Humboldt County, California, H. S. Barber.

Type examined.

*Arytaina robusta*† Crawford

(Figs. 6, 105, 106)

1914 *Arytaina robusta* Crawford, U. S. Nat. Mus., Bull. 85:123-124.1917 *Arytaina robusta* Van Duzee, Cat. Hemip. N. Am. 803.1920 *Arytaina montana* Crawford, Ent. News, 31:13-14.1932 *Arytaina robusta* Klyver, Ent. News, 43:39.1932 *Arytaina snowi* Dowell, Jour. Kans. Ent. Soc. 5:93-94.

Length to tip of folded wings 2.5 mm.

COLOR: Coloration extremely variable. General color from greenish or yellowish white to dark brown. Dorsum usually light, venter and legs darker. Often with considerable red marking, especially the genal processes. Forewings white with variable brown maculation, usually taking the form of two irregular, diffuse maculae separated by a broad

\* From *fuscus* -a -um, L. adj.—dark + *pennis*, L. irr. noun—wing.

† *robustus* -a -um, L. adj.—strong, solid.

immaculate band across wing beyond tip of clavus; often more or less evenly covered with small brown spots, with seven more-or-less persistent spots on margin. A white pulverulence commonly covers a greater or lesser portion of the insect, especially the forewings.

**STRUCTURE:** Head more or less deflexed, narrower than thorax. Vertex with broad, deep discal impressions, bulging anteriorly each side of anterior ocellus, twice as wide as long, lateral ocelli on slightly raised areas. Genal processes variable from bluntly cone-shaped to broadly rounded, contiguous basally, about  $\frac{2}{3}$  as long as vertex. Antennae somewhat over  $1\frac{1}{2}$  times as long as width of head. Thorax moderately arched. Pronotum deflexed, long. Forewings broad, narrowly rounded apically, slightly more than twice as long as wide (variable); costa very heavy, Rs short, sharply turned to costa, cubital cell larger than medial, pterostigma lacking or extremely small. Hind tibia with small basal spur.

**GENITALIA:** Male proctiger rather short, stout, slightly tapered. Forceps simple; in lateral view somewhat enlarged toward apices; in caudal view moderately stout, well arched; apices subacute, turned cephalad somewhat. Female genital segment a little shorter than rest of abdomen; dorsal valve longer than ventral, sharply concave in apical half, upturned apically, subacute, a tuft of long setae on dorsal hump; ventral valve shorter than dorsal, upturned, acute.

This species is very abundant throughout the western United States occurring in large numbers on *Ceanothus fendleri* and perhaps other species of *Ceanothus*. It is extremely variable as is usual in such abundant and widespread species, the coloration and pulverulence being especially erratic. In general the individuals from the southern part of its range have less definite wing maculae. Many specimens are at hand from numerous localities in the following states: Colorado, Wyoming, South Dakota, Montana, Idaho, Washington, Oregon, California, and Arizona. It is also recorded from Utah and British Columbia.

Type in Crawford's collection, apparently a specimen from Colorado, but no specimen so labeled.

Paratypes of both *A. snowi* Dowell and *A. montana* Crawford have been examined, and they are merely *robusta* in which the wing maculation is diffuse.

*Arytaina robusta sinuata*\* n. subsp.

(Fig. 289)

Similar to the typical form except as follows: Darker, general color chocolate brown; entirely devoid of pulverulence, including forewings; genal processes generally longer and nearer plane of vertex; veins of forewings more distinctly raised from membrane; R shorter, Rs therefore longer, M strongly sinuate; female genital segment longer, fully as long as rest of abdomen; dorsal valve straight on dorsal margin, attenuate, upcurved to blunt apex; ventral valve almost equalling dorsal.

\* *sinuatus*, L. (p. part., of *sinuo*)—wavy.

This form may represent a distinct species, or it may be merely another variant of *robusta*. As I have only four female specimens I am unwilling to designate it as of specific rank, but it is hoped that by naming it attention may be directed to it and its true taxonomic nature thereby determined.

HOLOTYPE, female, Moscow Mountain, Idaho, July 20, 1938, H. M. Harris, in author's collection.

Paratypes: Placer County, California, September, Koebele, (*Ceanothus cordulatus*) in United States National Museum; Big Bear Lake, California, July 26, 1932, R. H. Beamer in Snow Collection, University of Kansas; Colo. 2030, in Crawford Collection.

*Arytaina pubescens*\* Crawford

(Figs. 107, 108)

1914 *Arytaina pubescens* Crawford, U. S. Nat. Mus., Bull. 85:123, 131-132.

1917 *Arytaina pubescens* Van Duzee, Cat. Hemip. N. Am. 804.

1932 *Arytaina pubescens* Klyver, Ent. News 43:70-71.

Length to tip of folded wings 2 mm.

COLOR: General color light brown to red. Head mostly white. Dorsum of thorax more or less marked with white. Abdomen often green. Forewings white to hyaline, maculate with brown apically and along media.

STRUCTURE: Head and thorax with prominent white pubescence. Head slightly deflexed, as broad as thorax. Vertex  $\frac{3}{5}$  as long as wide, deeply emarginate anteriorly, lateral ocelli borne on prominently raised portions. Genal processes blunt, divergent, scarcely contiguous basally, slightly over  $\frac{1}{3}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax moderately arched, broad. Pronotum slightly descending anteriorly. Forewings short, broadly rounded, about twice as long as wide, somewhat coriaceous; Rs short, marginal cells equal, pterostigma small. Hind tibia with very small basal tubercle.

GENITALIA: Male proctiger short, broad basally then narrowed, curved caudad. Forceps short, stout, blunt, a slender black spine arising on mesal margin, as long as base, incurved apically. Female genital segment shorter than rest of abdomen; dorsal valve large basally, very abruptly narrowed to short, straight, subacute, apical portion; ventral valve largely covered by last sternite, a large lobe extending caudad overlapping dorsal valve, apex acute, nearly equalling dorsal valve.

Many specimens of this very distinct little species are at hand from California, Oregon, Nevada, Idaho, and Colorado. The host plant is *Purshia tridentata*.

Type in Crawford's collection (?), no labeled specimen.

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\* *pubescens*, L. (pres. part. of *pubescere*)—having hair, pubescent.



*Arytaina assimilis*\* Crawford

(Fig. 110)

1914 *Arytaina assimilis* Crawford, U. S. Nat. Mus., Bull. 85:123, 127-128.1917 *Arytaina assimilis* Van Duzee, Cat. Hemip. N. Am. 804.1932 *Arytaina assimilis* Klyver, Ent. News, 43:70.

I have seen no specimen of this species which was described from a unique male.

"Length of body 1.9 mm.; length of forewing 2.2; width of head 0.80. General color reddish brown, lighter on dorsum and head. Body rather small, long.

"Head relatively rather small, deflexed quite strongly, about as broad as thorax, punctate; vertex arcuate on posterior margin, with a deep fovea on each side of median line near center, slightly bulging in front on each side of median line, not strongly elevated on postocellar regions; genal cones rather short, contiguous at base, rounded broadly at apex, slightly pubescent. Antennae a little more than twice as long as width of head, slender.

"Thorax arched strongly, robust, punctate. Pronotum rather long, flat on dorsal surface; propleurites short. Wings small, subhyaline, maculate in middle and on hind margin conspicuously so, semitransparent, a little more than twice as long as broad, broadly rounded at apex and apical half of wing distinctly narrowing toward apex; first marginal cell larger than second; radial sector long and curved; pterostigma long, large at base.

"*Genitalia*: Male genitalia segment very large, about half as large as rest of abdomen; forceps moderately long, stout, roundly acute at tip; anal valve very large, larger than forceps, with a large, lobate protuberance on hind margin; pubescence short.

"Described from one male from Claremont, California (Crawford), on *Ceanothus crassifolius*. This form is manifestly distinct from *A. ceanothae*, but was taken on the same tree and together with the specimens of the other species.

"Type in author's collection."—Crawford.

Klyver records this species from several localities in California on species of *Ceanothus*.

*Arytaina spartiophila*† (Förster)

(Figs. 86, 109, 109a, 290)

1843 *Psylla spartii* Guérin, Iconographie du règne animal de G. Cuvier, Part IV:370 [fide Löw 1878].

[non] *Psylla spartii* Hartig, Germ. Zeitschr. Ent. 3:375. 1841.

1848 *Psylla spartiophila* Förster, Verh. natur. Ver. preuss. Rhein. 5:75.

1876 *Psylla spartiophila* Scott, Trans. Ent. Soc. London 1876:533.

1878 *Psylla spartii* Löw, Verh. zool-bot. Ges. Wien (1877) 27:126-129.

1908 *Psylla spartii* Sulc, Bull. Int. Acad. des Sciences Francois Joseph I (Prague) 12:248-252.

1913 *Psylla spartii* Aulmann, Psy. Cat. 27.

1935 *Psylla spartii* Haupt, Tierw. Mittell. 4, 3:233.

\* *assimilis* -e, L. adj.—similar.

† From *spartius*, Gr. noun—spanish broom + *philos*, Gr. noun—a lover.



Length to tip of folded wings 3 mm.

COLOR: General color light to dark brown. Abdominal segments dark brown except margins. Forewings somewhat yellowish, darker along veins.

STRUCTURE: Head nearly as broad as thorax, scarcely deflexed. Vertex with small discal foveae,  $\frac{3}{5}$  as long as wide, strongly produced anteriorly each side of median suture, lateral ocelli on raised areas. Genae swollen, rounded, nearly vertical, not touching,  $\frac{1}{3}$  as long as vertex. Median ocellus very large. Antennae twice as long as width of head. Thorax weakly arched. Pronotum long, descending anteriorly. Forewings  $2\frac{1}{2}$  times as long as wide, broadly rounded; Rs long, somewhat sinuate, marginal cells equal, pterostigma almost obsolete. Hind tibia with small basal spur.

GENITALIA: Male proctiger, long, slender, curved caudad. Forceps long and slender; in lateral view tapering slightly from base, apices black, curved caudad; in caudal view slender, strongly arched to black subacute apices, postero-medial margins densely pubescent. Female genital segment stout, about as long as rest of abdomen; dorsal valve longer than ventral, dorsal margin slightly sinuate, apically attenuate, black, acute, upturned; ventral valve very sharply upturned, truncate, slightly excavate apically.

Described from numerous specimens from Washon Island, Washington, May 1, 1940, W. W. Baker, taken on *Cytisus scoparius*; four female specimens taken at Fort Lewis and Dupont, Washington, July 5, 1935, P. W. Oman and R. H. Beamer.

Heretofore unrecorded from North America, this species has been introduced from Europe, probably with its host, *Cytisus scoparius*, which is well established in the coastal region of the Pacific Northwest.

Guérin first described this species in 1843, naming it *Psylla spartii*. He knew of Hartig's use of the name two years before but since he knew Hartig's species to be a synonym of *P. genistae* Latreille he used the name again, a homonym. In 1848 Förster, unaware of Guérin's work, redescribed the species as *Psylla spartiophila* which name is the correct one for the species. Löw had all these facts in mind but continued the use of *Psylla spartii*. This use of a homonym has continued until the present time.

Host: *Cytisus scoparius*. The name in use at the time of Guérin and Förster was *Spartium scoparium*.

### *Arytaina ceanothi*\* Crawford

(Figs. 111, 112)

1914 *Arytaina ceanothae* Crawford, U. S. Nat. Mus., Bull. 85:123, 130.

1917 *Arytaina ceanothae* Van Duzee, Cat. Hemip. N. Am. 804.

1932 *Arytaina ceanothae* Klyver, Ent. News 43:70.

\* Genitive of *Ceanothus*—generic name of its host plant. (The ending *ae* used by Crawford is evidently a *lapsus calami* and is emended to *i*.)

Length to tip of folded wings 2 mm.

COLOR: Yellowish to brown. Forewings more or less fumate.

STRUCTURE: Head small, narrower than thorax, deflexed. Vertex nearly twice as wide as long, discal impressions broad and deep, rounded anteriorly, emarginate medially. Genae swollen as small lobes, not touching and scarcely extending beyond anterior margin of vertex. Antennae about  $1\frac{2}{3}$  times as long as width of head. Thorax strongly arched. Pronotum descending. Forewings broadly rounded, about twice as long as wide or slightly over; cubital cell slightly larger than medial, pterostigma prominent, somewhat variable in size. Hind tibia without basal spur.

GENITALIA: Male proctiger slender, slightly tapering, curved caudad somewhat. Forceps very slender; in lateral view straight to rounded, black-tipped apices; in caudal view evenly arched. Female genital segment about as long as rest of abdomen; dorsal valve strongly concave, apical portion slender, apex subacute; ventral valve stout, dorsal margin excavate, acute.

Specimens at hand are from Los Angeles County, Siskiyou County, Mt. Shasta County, and Sta. Cruz Mountains, California; Easton, Washington; Haugan, Montana.

Host: *Ceanothus* (Crawford and Klyver).

Type designated as in Crawford Collection, but no specimen so labeled.

### *Arytaina amorphae*\* (Mally)

(Figs. 87, 88)

1895 *Psylla amorphae* Mally, Proc. Ia. Acad. Sci. 2:159.

1911 *Psyllopa floridensis* Crawford, Pom. Coll. Jour. Ent. 3:629.

1911 *Psyllopa ilicis* Crawford, Pom. Coll. Jour. Ent. 3:632.

1912 *Psyllopa ilicis* Crawford, Pom. Coll. Jour. Ent. 4:684.

1913 *Psylla amorphae* Aulmann, Psy. Cat. 10.

1914 *Arytaina amorphae* Crawford, U. S. Nat. Mus., Bull. 85:85.

1914 *Amblyrhina fractiforceps* Crawford, U. S. Nat. Mus., Bull. 85:130.

1917 *Arytaina amorphae* Van Duzee, Cat. Hemip. N. Am. 804.

Length to tip of folded wings 2.0 to 2.25 mm.

COLOR: General color light green to yellow, white longitudinal lines on thoracic dorsum, irregular white markings on vertex. Forewings more or less yellowish. Antennae dark apically.

STRUCTURE: Head deflexed, slightly narrower than thorax. Vertex with prominent discal impressions, definitely margined anteriorly,  $\frac{3}{5}$  as long as wide. Genae produced as short blunt processes  $\frac{1}{6}$  as long as vertex, not touching, extending forward, visible in dorsal view of vertex, a prominent suture between vertex and genae. Antennae short, about as long as width of head. Thorax well arched longitudinally, quite flat laterally. Pronotum strongly descending. Forewings long,  $2\frac{2}{3}$  times as long as wide; cubital petiole short, cubital cell elongate, larger than medial, pterostigma large. Hind tibia without basal spur.

\* Genitive of *Amorpha*—the generic name of its host.

**GENITALIA:** Male proctiger straight, moderately broad in lateral view, slightly converging toward apex. Subgenital plate elongate, rounded lobe on dorsal margin, apex swollen ventrad, a stout spine on caudal margin, extending dorso-caudad between forceps. Forceps in lateral view of moderate width basally, abruptly enlarged about midway, cephalic lobe much larger than caudal, dorsal margin evenly excavate; in caudal view stout, elbowed near apices to obliquely truncate apex; in dorsal view anterior lobes slightly turned mesad, a heavy truncate median lobe bearing several small stout black spines, a sharper caudal point bearing two black spines. Female genital segment somewhat shorter than rest of abdomen; dorsal valve longer than ventral, sinuate dorsally, apex blunt; ventral valve upcurved, acute.

This species and the following have been confused heretofore. They are very similar and live upon closely related plants, this form on *Amorpha fruticosa* the other on *Amorpha canescens*. Due to the small size of these insects, differences in structure which would be very noticeable in larger forms are easily passed by as of no consequence. In the original description of *amorphae*, Mally recorded the host plant as *A. fruticosa*. Crawford (1914) cites *A. canescens* labels on *amorphae*; these specimens are probably the related species. In June, 1940, large series of both species were taken on the same date and the same general locality, and sufficient difference was apparent in the field that they were kept very carefully separated in order to determine definitely their status. Upon microscopic examination, they have proved to be distinctly different. The most distinctive differences are in the size and shape of the vertex and genal processes and in the length of the antennae. Minor but apparently constant differences occur in the genitalia also.

The cotypic series (5 females) is in the Iowa State College Collection. One of the specimens is here designated as lectotype. Other specimens at hand are from various localities in Iowa, Kansas, Texas, Colorado, and Arizona.

Host: *Amorpha fruticosa*.

TYPE, female, I. A. C., 6/12/94, C. W. M., is in the Iowa State College Collection.

*Arytaina pallida*\* n. sp.

(Figs. 89, 90, 291)

Length to tip of folded wings 1.75 to 2.25 mm.

**COLOR:** General color greenish white to yellowish white. Forewings whitish to slightly fumate. Hind wings white. Antennae dark apically.

**STRUCTURE:** Head slightly deflexed, nearly as wide as thorax. Vertex with broad discal impressions, about  $\frac{1}{2}$  as long as wide, rounding down anteriorly, genae swollen, but scarcely produced; separated by full width of frons, not extending forward beyond anterior margin of vertex, suture between genae and vertex indistinct laterally. Antennae  $1\frac{1}{3}$  times as

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\* *pallidus* -a -um, L. adj.—pale.

long as width of head. Thorax well arched. Pronotum descending. Forewings  $2\frac{2}{3}$  times as long as wide; venation as in *amorphae*, pterostigma a little shorter. Hind tibia without basal spur.

**GENITALIA:** Male genitalia similar to *amorphae* but proctiger stouter. Forceps with petiolate base more slender, anterior lobe longer, scarcely produced caudad, dorsal margin strongly sinuate; in caudal view slender basally, enlarged apically, a stout incurving truncate tooth borne at apex; in dorsal view somewhat produced medially with an almost continuous row of black teeth to caudal margin. Female genital segment similar to *amorphae* but dorsal valve less sinuate, apex upturned, subacute, ventral valve more slender.

This species while very similar to *A. amorphae* Mally may be distinguished from it by the shorter and less protruding genal processes, the longer antennae, the upturned tip of the dorsal valve of the female genital segment, and the shape of the male forceps as shown in the figures.

It was taken abundantly on *Amorpha canescens*, its host plant, in June.

**HOLOTYPE**, male, **ALLOTYPE**, female, numerous **PARATYPES**, Turin, Iowa, June 1, 1940, L. D. Tuthill. Other **PARATYPES** (7) Eureka, Kansas, May 29, 1933, P. W. Oman; (1) Wilson County, Minnesota, July 1, 1922, P. B. Lawson; (4) Oakland, Nebraska, July 5, 1940, W. W. Wirth.

Holotype, allotype, and paratypes in author's collection. Paratypes in United States National Museum, University of Kansas, and University of Minnesota.

#### *Arytaina aculeata*\* Crawford

1914 *Arytaina aculeata* Crawford, U. S. Nat. Mus., Bull. 85:123, 131.

1917 *Arytaina aculeata* Van Duzee, Cat. Hemip. N. Am. 804.

1932 *Arytaina aculeata* Klyver, Ent. News 43:70.

Length to tip of folded wings 2 mm.

**COLOR:** Light brown with whitish markings on head and thorax. Forewings yellowish.

**STRUCTURE:** Head small, deflexed, as wide as thorax. Vertex rounded anteriorly, produced each side of median suture,  $\frac{2}{3}$  as long as wide, anterior margin abrupt, discal impressions prominent. Genal processes short, rounded, contiguous basally, less than  $\frac{1}{3}$  as long as vertex, scarcely visible in dorsal view. Antennae  $1\frac{1}{5}$  times as long as width of head. Thorax moderately arched. Forewings narrowed apically, somewhat rhomboidal, slightly coriaceous, about  $2\frac{1}{2}$  times as long as broad; Rs moderately long, straight, marginal cells equal, pterostigma small. Hind tibia without basal spur.

**GENITALIA:** Male unknown. Female genital segment longer than rest of abdomen, enlarged and globose basally, apical portion attenuate, styliform, black; dorsal valve slightly longer than ventral, both acute.

Known only from the female, this rare species has been taken only

\* *aculeatus* -a -um, L. adj.—pointed, sharp.

in California. Four specimens are at hand from Los Angeles County. Klyver records it is taken on *Cercocarpus betuloides*, Napa County, California.

TYPE, female, No. 18103 United States National Museum.

*Arytaina chelifera*\* Crawford

1914 *Arytaina chelifera* Crawford, U. S. Nat. Mus., Bull. 85:123, 128-129.

1914 *Brachysylla purshiae* Crawford, U. S. Nat. Mus., Bull. 85:129.

1917 *Arytaina chelifera* Van Duzee, Cat. Hemip. N. Am. 804.

Length to tip of folded wings 2 mm.

COLOR: "General color greenish yellow; genitalia, tip of antennae, and venter more or less browned; forewings very slightly fumate, browned a little darker on apical fourth."—Crawford.

STRUCTURE: Head nearly as broad as thorax, moderately deflexed. Vertex swollen and rounded anteriorly each side of median suture,  $\frac{3}{5}$  as long as wide. Genal processes cone-shaped, rounded at apex, divergent,  $\frac{1}{3}$  as long as vertex, depressed much below but parallel to plane of vertex. Antennae about as long as vertex. Thorax moderately arched. Pronotum quite flat. Forewings slightly rugose, hyaline, broadly rounded, somewhat over twice as long as wide; Rs short, slightly sinuate, marginal cells equal, pterostigma very short, but distinct. Hind wings thickly set with minute setae. Hind tibia with prominent basal spur.

GENITALIA: Male protiger small, straight, about as long as forceps. Forceps in lateral view stout, cephalic margin straight, caudal margin swollen, deeply notched apically, anterior process straight, subacute, not heavily sclerotized, posterior process extending antero-mesally, heavily sclerotized, black, curved, acute; in caudal view broad, black tooth-like processes arising from mesal margins, touching apically. Female genital segment very short; dorsal valve somewhat concave dorsally, apex elongate, acute, with many short setae; ventral valve upturned, acute apically.

Known only from the type series from Williams, Arizona; and American Fork Canyon, Utah. These specimens are now quite faded to a "museum tan." As Crawford notes, the Utah specimens were taken on *Purshia tridentata*, which is probably the host.

TYPE, female, No. 18102 United States National Museum, Williams, Arizona, Barber and Schwarz.

Type examined.

*Arytaina minuta*† Crawford

(Figs. 113, 114)

1914 *Arytaina minuta* Crawford, U. S. Nat. Mus., Bull. 85:123, 128.

1917 *Arytaina minuta* Van Duzee, Cat. Hemip. N. Am. 804.

1932 *Arytaina minuta* Klyver, Ent. News, 43:70.

\* Apparently from c(h)ele, Gr. noun—claw + fer from L. v. fero—bearing.

† minutus -a -um, L. adj.—small.



Length to tip of folded wings 2 to 2.5 mm.

COLOR: General color light brown, abdomen darker brown. Forewings clear brown, darker apically.

STRUCTURE: Head strongly deflexed, nearly as wide as thorax. Vertex nearly flat, discal impressions shallow, sloping downward anteriorly to genae, nearly twice as wide as long. Genal processes broad, rounded, contiguous,  $\frac{1}{3}$  as long as vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax well arched. Pronotum descending. Forewings slightly coriaceous, narrowly rounded,  $2\frac{1}{2}$  times as long as wide; Rs long, marginal cells equal in size, pterostigma prominent, slender, long. Hind tibia with small basal spur.

GENITALIA: Male genitalia large. Proctiger triangular, broad at base. Forceps slender in lateral view, slightly sinuate, apices black, subacute; in caudal view moderately broad, arched. Female genital segment very large, longer than rest of abdomen; dorsal valve longer than ventral, sinuate, apex attenuate, slightly upturned, subacute; ventral valve stout, acute.

Several males and females are at hand from Los Angeles County, Mint Canyon, and Del Mar, California. One specimen bears a label *Ceanothus rigidus*. Klyver records *Ceanothus cuneatus* as a definite host.

Crawford records the type as in his collection, but no specimen seems to have been so designated.

*Arytaina insolita*\* n. sp.

(Figs. 141, 142, 292)

Length to tip of folded wings 2.5 to 3 mm.

COLOR: Reddish brown. Forewings yellowish brown, darker along veins, males darker on genae and legs.

STRUCTURE: Head deflexed, narrower than thorax. Vertex nearly flat, bulging anteriorly each side of median suture, slight discal impressions, lateral ocelli borne on prominently raised areas. Genal processes parallel to plane of vertex, rounded apically, contiguous at base,  $\frac{1}{2}$  as long as vertex. Antennae slightly over  $1\frac{1}{2}$  times as long as width of head. Thorax well arched, broad. Pronotum descending. Forewings broadly rounded,  $2\frac{1}{2}$  times as long as wide; Rs of medium length, marginal cells large, equal, pterostigma almost completely lacking. Hind tibia without basal spur.

GENITALIA: Male genitalia very large. Proctiger long, apex slender, rest produced caudad as a large rounded lobe. Forceps in lateral view a little more than  $\frac{1}{2}$  as long as proctiger, slender, tapering apically to blunt, black tips; in caudal view slender, evenly arched to black apices, a dense fringe of setae mesally. Female genital segment very large, stout, longer than rest of abdomen; dorsal valve apically slender and upturned to subacute apex; ventral valve shorter than dorsal, strongly upturned, acute.

\* *insolitus* -a -um, L. adj.—unusual.



HOLOTYPE, male, ALLOTYPE, female, 3 male and 15 female PARATYPES with data: S. of Mt. Shasta Cy, California, June 29, 1935, P. W. Oman. Other PARATYPES as follows: 1 male and 2 females, Big Bear Lake, California, July 26, 1932, R. H. Beamer; 2 females, San Jacinto Mountains, California, July 21, 1929, R. H. Beamer; 1 male, Dunsmuir, California, June 29, 1935, R. H. Beamer; 1 female, Strawberry Dam, Utah, July 16, 1935, P. W. Oman; 1 male, Jacumba, and 1 female, Campo, California, May 18, 1941, D. J. and J. N. Knull.

HOLOTYPE, No. 55178 United States National Museum, allotype and paratypes in United States National Museum. Paratypes in University of Kansas, Ohio State University, and author's collections.

### Genus *Psyllopsis*\* Löw

- 1761 *Chermes* Linnaeus (*pro parte*), Faun. Svec.  
 1764 *Psylla* Geoffroy (*pro parte*), Hist. Abr. des Insectes 1.  
 1848 *Psylla* Förster, (*pro parte*), Verh. natur. Ver. preuss. Rhein. 5:73.  
 1877 *Psylla* Thomson, Opusc. Ent. 8:829 [as subgenus of *Chermes*].  
 1879 *Psyllopsis* Löw, Verh. zool.-bot. Ges. Wien 28:585, 587.  
 1896 *Psyllopsis* Edwards, Hemip.-Homop. Br. Is. 233.  
 1912 *Psyllopsis* Oshanin, Kat. paläa. Hemip. 126 [designates type].  
 1913 *Psyllopsis* Aulmann, Psy. Cat. 71.  
 1914 *Psyllopsis* Crawford, U. S. Nat. Mus., Bull. 85:132.  
 1917 *Psyllopsis* Van Duzee, Cat. Hemip. N. Am. 804.

Head narrower than thorax, deflexed. Vertex rounding smoothly into genae anteriorly. Genae produced as conical processes, more or less divergent, deflexed sharply from plane of vertex. Antennae rather long, distinctly longer than width of head. Eyes hemispherical, of moderate size. Thorax well arched. Pronotum descending anteriorly, rather long. Propleural suture ending medially on lateral margin of pronotum. Forewings membranous, broadly rounded apically, pterostigma present. Metatibia without basal armature, with a row of small black apical spines. Metatarsus with two black clawlike spines.

Logotype: *Psyllopsis fraxinicola* (Förster)

### Key to the Species of *Psyllopsis*

1. Unicolorous, including wings.....*fraxinicola* p. 516.  
 Dark brown or black markings on body and forewings.....2.
2. Male forceps in lateral view with a caudal lobe, anterior margin nearly straight  
*fraxini* p. 518.  
 Male forceps in lateral view very much enlarged apically, quadrate  
*discrepans* p. 518.

### *Psyllopsis fraxinicola*† (Förster)

(Figs. 115, 116, 117, 117a, 249)

- 1848 *Psylla fraxinicola* Förster, Verh. natur. Ver. preuss. Rhein. 5:73.  
 1848 *Psylla viridula* Förster, Verh. natur. Ver. preuss. Rhein. 5:74.

\* *Psylla* + *opsis* -is, Gr. f. noun—the aspect, the appearance.

† From *Fraxinus*—generic name of the host + *cola*, L.—inhabitant.

- 1861 *Psylla unicolor* Flor, Rynch. Liv. 2:449, 479.  
 1861 *Psylla unicolor* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 340, 347, 353.  
 1872 *Psylla fraxinicola* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:398.  
 1872 *Psylla chlorogenes* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:399.  
 1872 *Psylla viridula* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:399.  
 1876 *Psylla fraxinicola* Scott, Trans. Ent. Soc. London 1876:544.  
 1877 *Chermes fraxinicola* Thomson, Opusc. Ent. 8:829.  
 1879 *Psyllopsis fraxinicola* Löw, Verh. zool.-bot. Ges. Wien 28:588.  
 1896 *Psyllopsis fraxinicola* Edwards, Hemip.-Homop. Br. Is. 234.  
 1908 *Psyllopsis fraxinicola* Oshanin, Verz. palae. Hemip. 2:348.  
 1910 *Psyllopsis fraxinicola* Smith, Ins. N. J. 108.  
 1912 *Psyllopsis fraxinicola* Oshanin, Kat. paläa. Hemip. 126 [designated type].  
 1913 *Psyllopsis fraxinicola* Aulmann, Psy. Cat. 73.  
 1914 *Psyllopsis fraxinicola* Crawford, U. S. Nat. Mus., Bull. 85:132.  
 1917 *Psyllopsis fraxinicola* Van Duzee, Cat. Hemip. N. Am. 805.  
 1923 *Psyllopsis fraxinicola* Patch, Hemip. Conn. 250.  
 1923 *Psyllopsis fraxinicola* Ferris, Can. Ent. 55:251-254 [figs. nymph].  
 1935 *Psyllopsis fraxinicola* Haupt, Tierw. Mittel. 4, 3:230.

Length to tip of folded wings 3.5 mm.

COLOR: Uniformly greenish yellow except tips of antennae. Wings hyaline.

STRUCTURE: Head deflexed, narrower than thorax. Vertex evenly excavate,  $\frac{2}{3}$  as long as wide, anteriorly rounding down to genae without a visible suture between latter and vertex, discal impressions small, distinct. Genal processes cone-shaped, subacute, somewhat divergent, nearly vertical, less than  $\frac{1}{2}$  as long as vertex. Antennae nearly twice as long as width of head. Thorax strongly arched. Pronotum broad, rather long, descending. Forewings large, very broadly rounded apically, slightly over twice as long as wide, membrane thickly set with minute setae; Rs very long, medial cell elongate, about equal in size to cubital, pterostigma very large. Hind tibia without basal armature.

GENITALIA: Male genitalia large. Subgenital plate elongate, slender. Proctiger curved on cephalic margin, caudally produced in basal half as a triangular lobe. Forceps short with large anterior lobe, narrow at point of origin then enlarged, very broad apically, convexly rounded, caudal portion stout, converging; in caudal view posterior lobes black-tipped, serrate, touching, apices of anterior lobes touching. Female genital segment shorter than rest of abdomen; dorsal valve with a short styliform portion apically, blunt, slightly downcurved; ventral valve in lateral view upcurved, acute, in ventral view broad basally then narrow, deeply and narrowly excavate apically, heavily pubescent.

Specimens are at hand from Washington, D. C.; Atlantic City, New Jersey; Kings County, Nova Scotia; Stanford University, California. It is also recorded from Connecticut and Idaho. Felt (26th Rept. N. Y. Sta. Ent.) reported it from New York, but this is based on a misidentification. It probably does occur in New York and many other states, however. Outside North America its distribution embraces all of Europe in which its host occurs. In Europe it seems to be limited to *Fraxinus excelsior*; in North America it has been recorded also on *Fraxinus dipetala* and *Juglans*.

*Psyllopsis fraxini*\* (Linnaeus)

(Fig. 118)

- 1761 *Chermes fraxini* Linnaeus, Faun. Svec. 264.  
 1848 *Psylla fraxini* Förster, Verh. natur. Ver. preuss. Rhein. 5:80.  
 1861 *Psylla fraxini* Flor, Rhynch. Liv. 2:481.  
 1861 *Psylla fraxini* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 340, 347, 353.  
 1872 *Psylla fraxini* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:395.  
 1876 *Psylla fraxini* Scott, Trans. Ent. Soc. London 1876:545.  
 1877 *Chermes fraxini* Thomson, Opusc. Ent. 8:829.  
 1877 *Chermes sorbi* Thomson (pro parte), Opusc. Ent. 8:829.  
 1879 *Psyllopsis fraxini* Löw, Verh. zool.-bot. Ges. Wien 28:589.  
 1896 *Psyllopsis fraxini* Edwards, Hemip.-Homop. Br. Is. 234, pl. 26, fig. 6.  
 1908 *Psyllopsis fraxini* Oshanin, Verz. palae. Hemip. 2:348.  
 1911 *Psyllopsis fraxinicola* Felt, N. Y. Sta. Mus., Bull. 147:39-40, pls. 15, 16.  
 1913 *Psyllopsis fraxini* Aulmann, Psy. Cat. 72.  
 1935 *Psyllopsis fraxini* Haupt, Tierw. Mittel. 4, 3:230.

Length to tip of folded wings 3.5 mm.

COLOR: General body color yellow with dark brown to black markings as follows: Disc and posterior margin of vertex, two large spots on prescutum, four longitudinal stripes on scutum, abdominal tergites except margins, portions of legs, venter and genitalia. Forewings with a large, irregular, marginal, apical macula, another at apex of clavus.

STRUCTURE: Very similar to *fraxinicola* except wings smaller, pterostigma shorter, Rs shorter, medial cell less elongate, much smaller than cubital.

GENITALIA: Male genitalia large. Subgenital plate slightly elongate. Proctiger produced caudad basally as a bluntly rounded lobe. Forceps erect; in lateral view narrow basally, nearly straight on cephalic margin, produced caudad as a blunt lobe, apices rounded; in caudal view stout, nearly straight, a very small mesal lobe basally. Female genital segment very similar to *fraxinicola*.

This species is represented in the Iowa State College Collection by a series of specimens collected in Buffalo, New York, July, 1886 and 1888, by E. P. Van Duzee. It has not heretofore been recorded from North America. Felt (1911) describes and figures a species occurring on ash which was determined for him as *P. fraxinicola*; it is apparent from his description and figures that *P. fraxini* was the species he had, however. He reported considerable damage to the foliage of ash (*Fraxinus*), its host. Recorded heretofore from all of Europe, including Scandinavia, Russia, Syria, and Palestine.

*Psyllopsis discrepans*† (Flor)

(Fig. 119)

- 1861 *Psylla discrepans* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 340, 347, 353, 376.  
 1877 *Chermes sorbi* Thomson, Opusc. Ent. 8:829.  
 1879 *Psyllopsis discrepans* Löw, Verh. zool.-bot. Ges. Wien 28:590.  
 1908 *Psyllopsis discrepans* Oshanin, Verz. palae. Hemip. 2:349.  
 1935 *Psyllopsis discrepans* Haupt, Tierw. Mittel. 4, 3:230.

\* Genitive of *Fraxinus*—the generic name of the host.

† Pres. part. of *discrepo*, L. v.—to differ.

A single male in the National Museum from Kings County, Nova Scotia, July 1, 1921, is apparently this species. It resembles *P. fraxini* closely except in darker coloration, more extensive maculation of the forewing and in genitalia.

Male genitalia very large. Subgenital plate elongate. Proctiger with rounded caudal lobe as in *fraxini*. Forceps in lateral view erect, narrow basally, abruptly enlarged into a quadrate apical portion, slightly excavate dorsally; in caudal view very heavy, slender and incurved apically, a small basal mesal lobe.

Its recorded distribution is Central Europe and Scandinavia.

### Genus *Euphalerus*\* Schwarz

- 1904 *Euphalerus* Schwarz, Proc. Ent. Soc. Wash. 6:238.  
 1913 *Euphalerus* Aulmann, Psy. Cat. 74.  
 1914 *Euphalerus* Crawford, U. S. Nat. Mus., Bull. 85:118.  
 1914 *Cephalopsylla* Crawford, U. S. Nat. Mus., Bull. 85:121, 122.  
 1917 *Euphalerus* Van Duzee, Cat. Hemip. N. Am. 802.  
 1937 *Euphalerus* Tuthill, Jour. Kans. Ent. Soc. 10:69-70.

Head deflexed, broad. Vertex plane or nearly so. Genae produced as large processes, rounded apically, on same plane as vertex, more or less divergent. Antennae short (less than  $1\frac{1}{2}$  times width of head). Eyes more or less recessive over propleurites, not elongate. Thorax quite strongly arched. Pronotum not extending far down laterally; terminating in a knoblike swelling. Propleurites equal in length dorsally, suture terminating at middle of lateral margin of pronotum. Forewings membranous or somewhat thickened and rugose, rounded or oblique apically. Metatibia with basal spur. Basal segment of metatarsus with two black clawlike spines.

Orthotype: *Euphalerus nidifex* Schwarz.

Some of the western species of this genus show a marked relationship to *Arytaina*.

### Key to the Species of *Euphalerus*

1. Forewings not rugose, body and forewings light in color with many minute brown spots.....**nidifex** p. 520.  
    Forewings rugose, body and forewings not covered with minute brown spots.....2.
2. Meso and metascutellum produced dorsad, cone-shaped.....3.  
    Meso and metascutellum not at all or scarcely produced.....4.
3. Forewings strongly rhomboidal.....**propinquus** p. 521.  
    Forewings rounded apically.....**jugovenosus** p. 521.
4. Uniformly red or reddish brown in color; without a tubercle ventrad of antennal insertion; male forceps not simple.....5.  
    Not uniformly reddish in color; with a more or less prominent tubercle ventrad of antennal insertion; male forceps simple.....6.
5. Larger species (3.75 mm. to tip of folded wings); genal processes nearly as long as vertex.....**adustus** p. 522.

\* Apparently from Gr. prefix *eu*—true, very + *phalerus*, Gr. adj.—clear, bright. (application obscure).

- Smaller species (2.5 mm. to tip of folded wings); genal processes  $\frac{3}{4}$  as long as vertex.....*tantillus* p. 523.  
 6. General color whitish; forewings with at least one dark macula at apex of clavus.....*vermiculosus* p. 524.  
 General color green (sometimes reddish) with many small white spots; forewings without dark maculae.....*rugipennis* p. 525.

*Euphalerus nidifex*\* Schwarz

(Figs. 120, 121, 122, 256)

- 1904 *Euphalerus nidifex* Schwarz, Proc. Ent. Soc. Wash. 6:238-239 and 153-154.  
 1913 *Euphalerus nidifex* Aulmann, Psy. Cat. 74.  
 1914 *Euphalerus nidifex* Crawford, U. S. Nat. Mus., Bull. 85:119.  
 1914 *Euphalerus ficus* Crawford, U. S. Nat. Mus., Bull. 85:120.  
 1917 *Euphalerus nidifex* Van Duzee, Cat. Hemip. N. Am. 802.  
 1937 *Euphalerus nidifex* Tuthill, Jour. Kans. Ent. Soc. 10:72.

Length to tip of folded wings 2 mm.

COLOR: "Color pale ochre-yellow varying to greenish yellow or reddish yellow, head, thorax, wings, and legs speckled with minute black or brown dots, wings slightly whitish."—Schwarz.

STRUCTURE: Head narrower than thorax, vertical, finely punctate. Vertex  $\frac{3}{5}$  as long as wide, nearly plane, somewhat bulging anteriorly, discal impressions prominent. Genal processes large, on same plane as vertex, rounded apically,  $\frac{2}{3}$  as long as vertex. Antennae slightly longer than width of head. Eyes rounded, recessive. Thorax finely punctate, strongly arched. Pronotum narrow, long, nearly vertical. Forewings not rugose, broadly rounded, membrane thickly set with minute setae, a little more than twice as long as wide; Rs long, nearly straight, cubital cell larger than medial, pterostigma large, unusually broad, not elongate. Hind wings equalling forewings. Hind tibia with small basal spur.

GENITALIA: Male proctiger slender, straight, truncate. Forceps small; in lateral view broad basally, tapered to acute black apices, slightly turned caudad; in caudal view broad, arched to mesally truncate opposing tips. Female genital segment small; dorsal valve straight, slender apically, blunt-tipped; ventral valve nearly as long as dorsal, upcurved, acute.

Described from specimens in the United States National Museum from Key West, Florida. Dr. John Caldwell in a private communication informs me that he has specimens taken on Key Largo, Florida. As the latter is but a stone's throw from the mainland this beautifully spotted species undoubtedly occurs in the southern part of that state. Its host plant is *Piscidia erythrina*. Schwarz reared the nymphs but gives only a few notes concerning its habits, these chiefly concern the nestlike structure in which they live on the ventral side of the leaves.

Known from Cuba and the Virgin Islands in addition to the localities mentioned above.

TYPE, No. 8146 United States National Museum, is missing.

\* From *nidus* -i, L. noun—nest + *fax* (faex)—dregs.



*Euphalerus propinquus*\* Crawford

(Fig. 251)

1914 *Euphalerus propinquus* Crawford, U. S. Nat. Mus., Bull. 85:119, 122.1914 *Cephalopsylla latifrons* Crawford, U. S. Nat. Mus., Bull. 85:122.1917 *Euphalerus propinquus* Van Duzee, Cat. Hemip. N. Am. 803.1937 *Euphalerus propinquus* Tuthill, Jour. Kans. Ent. Soc. 10:72.

Length to tip of folded wings 3 mm.

COLOR: General color white to light green with red dots and vermiculations on head and thorax. Forewings nearly transparent, dark from clavus to apex, many small brown spots in darkened area, apical margin alternately black and white, small opaque white spots on veins.

STRUCTURE: Head large, broader than thorax, rugose. Vertex broad, twice as wide as long, nearly plane, discal impressions very broad, shallow. Genal processes large, broad, swollen, continuous with vertex, roundly truncate,  $\frac{1}{2}$  as long as vertex, pubescent. Antennae  $1\frac{1}{4}$  times as long as width of head, a small tubercle ventrad of insertion. Thorax rugose, very strongly arched. Pronotum descending anteriorly. Meso- and metascutellum conically produced dorsad. Latter with a smaller protuberance on each side. Forewings rhomboidal, rugose; Rs somewhat sinuate, sharply curved to costa, not attaining apex of wing, M somewhat sinuate, marginal cells about equal, pterostigma of moderate size. Hind tibia with small basal spur. Legs heavily pubescent.

GENITALIA: Male proctiger short, stout, straight, parallel-sided, rounded apically. Forceps nearly as long as proctiger, with long pubescence; in lateral view broad, straight, enlarged toward apices, notched apically, anterior portion rounded, blunt, caudal part produced as a long, slender, curving, black tooth, projecting cephalad and mesad, acute; in caudal view stout, curved outward basally then straight to incurving apical portion. Female genital segment about as long as rest of abdomen, with long sparse pubescence; dorsal valve strongly upcurved, subacute; ventral valve shorter than dorsal, thick, strongly upcurved from base, dorsal margin strongly sinuate, apex acute.

Numerous specimens are at hand from the Chiracahua, Huachuca, and Santa Rita Mountains of Arizona, some of which were taken on *Amorpha fruticosa*, some swept from walnut. The type series was taken on *Ceanothus*. The latter is probably the host.

TYPE, female, No. 18100 United States National Museum, Arizona, Morrison.

Type examined.

*Euphalerus jugovenosus*† Tuthill

(Figs. 143, 144, 293)

1937 *Euphalerus jugovenosus* Tuthill, Jour. Kans. Ent. Soc. 10:70, 74.

\* *propinquus* -a -um, L. adj.—near.

† From *jugosus* -a -um, L. adj.—mountainous + *venosus* -a -um, L. adj.—veiny.



Length to tip of folded wings 2.5 to 3 mm.

COLOR: Head, pronotum, and prescutum white, with more or less vermiculate red markings; remainder of thorax dark red; legs somewhat lighter. Forewings hyaline except apex dark through cubital cell, latter black, apical margin alternately black and white; veins with rather regular opaque whitish areas and irregular red spots. Abdomen green, male genitalia and tip of female genital segment red.

STRUCTURE: Head, pronotum, and prescutum rugose, rest of body punctate. Head broader than thorax, deflexed. Vertex nearly plane, twice as wide as long, posterior margin almost straight, discal impressions large. Genal processes large, a little more than  $\frac{1}{2}$  as long as vertex, very broad, somewhat divergent, blunt apically, moderately pubescent. Antennae about as long as width of head, a small tubercle ventrad of insertion. Thorax very strongly arched. Pronotum nearly vertical. Prescutum with a small raised epiphysis on each corner caudally. Meso and metascutellum produced as heavy conical process. Forewings short, narrowly rounded, rugose, twice as long as wide; veins very prominent, marginal cells small, cubital somewhat larger, Rs sinuate, pterostigma moderately broad, very short. Small basal tubercle on hind tibia. Legs moderately pubescent.

GENITALIA: Male proctiger very stout, produced caudad as a broad lobe. Forceps straight, tapering to slender twisted black apices extending mesad, acute, moderately broad in lateral view. Female genital segment shorter than rest of abdomen, large basally, strongly narrowed; dorsal valve sharply upturned, acute apically, a tuft of long setae before slender apical portion; ventral valve shorter than dorsal, upturned, acute.

In addition to the type series from Lockwood and Monterey, California, specimens from Los Angeles County, Alameda County, Santa Cruz Mountain, and Delta in the same state are at hand.

TYPE, male, Lockwood, California, in Snow Collection, University of Kansas.

*Euphalerus adustus*\* Tuthill

(Figs. 145, 146, 294)

1937 *Euphalerus adustus* Tuthill, Jour. Kans. Ent. Soc. 10:70.

Length to tip of folded wings 3.75 mm.

COLOR: Uniformly yellowish red, often with some white vermiculations on head and thoracic dorsum. Forewings hyaline, yellow. Abdomen sometimes green.

STRUCTURE: Body large, punctate. Head deflexed, as broad as thorax. Vertex plane, pubescent anteriorly, twice as wide as long, discal impressions slight. Genal processes cone-shaped, large, swollen, subacute, divergent, prominently pubescent, as long as vertex medially, on same plane as vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax

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\* *adustus* -a -um, L. adj.—sunburned.

strongly arched. Pronotum moderately long, descending. Forewings long, rugose,  $2\frac{1}{2}$  times as long as wide; Rs somewhat sinuate, marginal cells about equal, pterostigma prominent, short but broad; three prominent radular areas on margin. Hind wings long, nearly equalling forewings. A large spur on base of hind tibia.

GENITALIA: Male proctiger short, straight, stout. Forceps large, almost as long as proctiger; in lateral view very broad, straight, parallel-margined; in caudal view broad basally, narrower apically, slightly arched; anterior margin heavily pubescent to roundly truncate apex, caudo-mesal margin produced as heavy, slightly bifid tooth, extending barely beyond apex. Female genital segment shorter than rest of abdomen; dorsal valve slightly longer than ventral, straight, acute; ventral valve attenuate, strongly upturned, apex black, acute.

Besides the type series from Utah and Colorado, about 20 specimens of both sexes from several localities in Utah are before me. Some of those taken in the Wasatch Mountains by Koebele and accompanied by nymphs bear labels, "*Cercocarpus ledifolius*."

TYPE, male, in Snow Collection, University of Kansas.

*Euphalerus tantillus*\* Tuthill

(Figs. 147, 148, 295)

1936 *Euphalerus tantillus* Tuthill, Jour. Kans. Ent. Soc. 10:70, 71.

Length to tip of folded wings 2.5 mm.

COLOR: Uniformly red to brownish red, indistinct lighter markings on head and thorax. Forewings reddish fumate.

STRUCTURE: Head as wide as thorax, strongly deflexed. Vertex twice as wide as long, nearly plane, discal impressions very broad, somewhat bulging anteriorly, slightly pubescent on anterior margin. Genal processes large, conical,  $\frac{2}{3}$  as long as vertex, on nearly same plane as vertex. Antennae slightly longer than width of head. Thorax moderately arched. Pronotum nearly vertical. Forewings somewhat rugose, short, slightly over twice as long as wide, three radular areas on margin; Rs slightly sinuate, marginal cells equal, pterostigma small. Hind wings nearly as long as forewings, thickly set with minute setae. A very small basal spur on hind tibia.

GENITALIA: Male proctiger large, stout, parallel-sided to truncate apex. Forceps about  $\frac{2}{3}$  as long as proctiger; in lateral view broad, enlarged apically; in caudal view broad at base, sharply narrowed, then moderately broad to apices; caudo-mesal margin produced cephalad apically, in dorsal view forceps appear double; heavy pubescence on caudal margin. Female genital segment about as long as rest of abdomen, large basally, suddenly narrowed, acuminate; dorsal valve longer than ventral, acute, styliform portion slightly upcurved, radulate, spines retrorse, basal portion with short even pubescence, a tuft of very long

\* *tantillus* -a -um, L. adj.—so small.

setae at base of styliform portion; ventral valve acute, a tuft of long setae on basal portion.

Known only from the type series from Salt Lake City, Utah.

TYPE, male, in Snow Collection, University of Kansas.

*Euphalerus vermiculosus*\* Crawford

(Figs. 123, 124, 125)

1914 *Euphalerus vermiculosus* Crawford, U. S. Nat. Mus., Bull. 85:119, 121.

1914 *Cephalopsylla ceanothi* Crawford, U. S. Nat. Mus., Bull. 85:122.

1917 *Euphalerus vermiculosus* Van Duzee, Cat. Hemip. N. Am. 803.

1932 *Euphyllerus vermiculosus* Klyver, Ent. News. 43:39.

1937 *Euphalerus vermiculosus* Tuthill, Jour. Kans. Ent. Soc. 10:72.

1937 *Euphalerus beameri* Tuthill, Jour. Kans. Ent. Soc. 10:70, 73.

Length to tip of folded wings 3 mm.

COLOR: General color greenish white to yellow, more or less brown on thoracic dorsum. Forewings hyaline, somewhat yellowish, to whitish opaque, at least one black spot at apex of clavus, usually fumate along apical margin, margin alternately black and white.

STRUCTURE: Head large, as broad as thorax, strongly deflexed, rugose. Vertex somewhat concave, over  $\frac{1}{2}$  as long as wide, discal impressions broad. Genal processes continuous with vertex, large, bluntly conical, swollen basally,  $\frac{3}{4}$  as long as vertex. Antennae less than  $1\frac{1}{2}$  times as long as width of head, a small tubercle ventrad of insertion. Eyes large, strongly recessive. Thorax very strongly arched, both laterally and longitudinally, coarsely granular. Pronotum long, strongly descending, with small raised prominences laterally. Forewings small, slightly over twice as long as wide, broadly rounded, rugose; Rs sinuate, long, marginal cells about equal, pterostigma of moderate size. Hind wings equalling forewings. Hind tibia with basal spur.

GENITALIA: Male proctiger moderately short, stout, straight, caudal margin slightly swollen, truncate apically. Forceps in lateral view straight, slightly swollen toward rounded apices, a large, black tooth apically, curving cephalo-mesad; in caudal view slender, strongly arched. Female genital segment almost as long as rest of abdomen, stout; dorsal valve slender apically, upturned, blunt; ventral valve nearly as long as dorsal, upturned, acute, dorsal margin sinuate.

Many specimens of this *Ceanothus*-inhabiting species are at hand from California, Oregon, Idaho, and Montana.

The form described as *E. beameri* is not sufficiently distinct to warrant a specific designation, the chief difference being in the forewings, and intermediate forms have come to light. As a matter of fact it appears that the type specimen of *vermiculosus* is the form called *beameri*.

TYPE, male, mountains near Claremont, California, Baker, in the Crawford Collection.

\* *vermiculosus* -a -um, L. adj.—wormy.

*Euphalerus rugipennis*\* Crawford

(Figs. 126, 127)

- 1914 *Euphalerus rugipennis* Crawford, U. S. Nat. Mus., Bull. 85:119, 120.  
1914 *Euphalerus rugipennis* var. *immaculatus* Crawford, U. S. Nat. Mus., Bull. 85:121.  
1914 *Cephalopsylla rugipennis* Crawford, U. S. Nat. Mus., Bull. 85:121.  
1917 *Euphalerus rugipennis* Van Duzee, Cat. Hemip. N. Am. 803.  
1917 *Euphalerus rugipennis* var. *immaculatus* Van Duzee, Cat. Hemip. N. Am. 803.  
1937 *Euphalerus rugipennis* Tuthill, Jour. Kans. Ent. Soc. 10:72.

Length to tip of folded wings 2.5 mm.

COLOR: Usual color uniformly green, more or less completely covered with small white spots, sometimes partly or entirely red.

STRUCTURE: Head coarsely punctate, as broad as thorax, deflexed. Vertex nearly plane, fully twice as wide as long, anterior margin slightly bulging medially, discal impressions shallow. Genal processes large, broad, bluntly rounded, divergent, not contiguous, heavily pubescent,  $\frac{1}{2}$  as long as vertex or more, on same plane as vertex. Antennae  $1\frac{1}{4}$  times as long as width of head, a small tubercle ventrad of insertion. Thorax well arched, coarsely punctate. Pronotum descending anteriorly. Forewings coarsely rugose, thickened, semitransparent, twice as long as wide; Rs sinuate, marginal cells about equal in size, pterostigma rather small, not prominent. Hind wings nearly equalling forewings. Legs short, pubescent. Small basal spur on hind tibia.

GENITALIA: Male proctiger stout, somewhat swollen caudad. Forceps straight, heavily pubescent, especially on caudo-mesal margin; in lateral view moderately slender; in caudal view very slightly arched to apices which are black and sharply curved mesad; black apical tooth extending cephalo-mesad, acute. Female genital segment shorter than rest of abdomen, stout, with long sparse pubescence; dorsal valve sharply upcurved, subacute, a cluster of small setae at apex; ventral valve shorter than dorsal, strongly upcurved, acute, dorsal margin sinuate.

Many specimens of this beautiful little species are at hand from numerous localities in Arizona, California, and Oregon. Numerous specimens from California bear the label *Ceanothus cuneatus* Nutt. One series of teneral specimens and nymphs from Los Angeles County, California, bears a label *Ceanothus rigidus* Nutt. Apparently several species of *Ceanothus* may serve as host.

TYPE, male, No. 18099 United States National Museum, Oracle, Arizona, Hubbard and Schwarz. The type is in poor condition, the head and wings of one side being gone.

Type examined.

The specimen which Crawford described as *E. rugipennis* var. *immaculatus* is in the United States National Museum and according to Oman is merely a teneral specimen.

\* From *rugosus* -a -um, L. adj.—wrinkled + *pennis*, L. irr. noun—wing.

Genus *Euphyllura*\* Förster

- 1839 *Thrips* O. G. Costa (pro parte), Monogr. degl' insetti ospitanti sull' olivo e nelle olive, 2 ed. Napoli 23-25 (larva) [*fide* Aulmann].  
 1840 *Psylla* Boyer de Fons-Colombe (pro parte), Ann. Soc. Ent. Fr. 9:111.  
 1848 *Euphyllura* Förster, Verh. natur. Ver. preuss. Rhein. 5:93.  
 1861 *Euphyllura* Flor, Bull. Soc. Imp. Nat. Moscou 34:337, 416-422.  
 1872 *Euphyllura* Meyer-Dür, Mitt. Schw. Ent. Ges. 3:380, 403.  
 1879 *Euphyllura* Löw, Verh. zool.-bot. Ges. Wien 28:607.  
 1904 *Euphyllura* Schwarz, Proc. Ent. Soc. Wash. 6:234.  
 1912 *Euphyllura* Oshanin, Kat. paläa. Hemip. 126 [designates type].  
 1913 *Euphyllura* Aulmann, Psy. Cat. 67.  
 1914 *Euphyllura* Crawford, U. S. Nat. Mus., Bull. 85:115.  
 1917 *Euphyllura* Van Duzee, Cat. Hemip. N. Am. 802.  
 1921 *Platystigma* Enderlein, Zool. Anz. 52:116.  
 1921 *Syntomoza* Enderlein, Zool. Anz. 52:117.

Head large, strongly deflexed, not vertical, as broad as thorax or broader. Eyes large, elongate, strongly recessive, extending back over propleurites. Vertex rather flat, more or less notched above, or extending over base of antennae, a tubercle next eye. Genal processes on same plane as vertex, very broad, blunt, usually rectangular, contiguous. Antennae shorter than width of head. Thorax very strongly arched, pronotum strongly descending, extending far down laterad. Forewings rhomboidal, coriaceous, more or less rugose, venation somewhat variable, pterostigma variable from large to obsolete. Hind tibia without basal spur, with several black spines apically. Two black claws on basal segment of metatarsus.

LOGOTYPE: *Euphyllura olivina* O. Costa.

Enderlein erected the genus *Platystigma* for those species which have a pterostigma but are without, usually entirely without, cross veins in the pterostigma and with the cubitus of the hind wings not branched. In this group he included all of the North American species, some of which have a pterostigma and some of which do not. As the pterostigma is very weak and variable in the entire group, I think its presence or absence certainly not of sufficient importance to warrant a separate genus. The so-called cross veins in *olivina* are so slight as to be scarcely significant specifically. I do not consider the venation of the hind wings of much significance as the entire wings are somewhat vestigial in some members of the family, and the veins are very weak in almost all.

*Syntomoza* was distinct from *Platystigma* solely in the lack of a pterostigma.

Key to the Species of *Euphyllura*

1. Veins Rs and M (including branches) of forewing very strongly sinuate.....2.  
    Rs and M not or but very slightly sinuate.....3.
2. Eyes elongate, strongly recessive, extending to mesonotum; forewings brown basally, light apically.....*arbuti* p. 528.  
    Eyes rounded, not strongly recessive, not covering prothoracic pleurites; forewings uniformly brown.....*arbuticola* p. 529.

\* Derivation obscure.



3. Unicolorous red to brown to black . . . . . 4.  
     Not unicolorous red to black, forewings with white maculae, entirely light or  
     entire body and forewings light with minute brown spots . . . . . 5.
4. Vertex plane, not swollen nor rounded down anteriorly; genal processes on  
     same plane as vertex; antennae  $\frac{2}{3}$  as long as width of head . . . . . *arctostaphyli* p. 529.  
     Vertex swollen anteriorly, rounded down to genae; genal processes deflexed  
     from plane of vertex; antennae  $\frac{1}{2}$  as long as width of head . . . . . *separata* p. 532.
5. Forewings red with two transverse white maculae  
     *arctostaphyli* var. *bifasciata* p. 531.  
     Forewings unicolorous . . . . . 6.
6. Forewings white or cream, head and thoracic dorsum red . . . . . 7.  
     Body and forewings whitish with numerous minute brown dots, evenly scattered  
     over surface; more or less covered with large flaky wax granules . . . . . *pruinosa* p. 531.
7. Forewings with a loose, snowy white pulverulence; female genital segment short,  
     dorsal valve not sinuate, about as long as ventral . . . . . *niveipennis* p. 531.  
     Forewings cream, without loose pulverulence; female genital segment long,  
     dorsal valve sinuate, attenuate, longer than ventral . . . . . *bicolor* p. 532.

*Euphyllura olivina*\* (Costa)

(Figs. 128, 129, 130, 257)

- 1839 *Thrips olivinus* O. G. Costa, Monogr. degl'insetti ospitanti sull'olivo e nelle olive,  
 2 ed., Napoli pp. 23-25.—Larve [*fide* Aulmann].
- 1840 *Psylla oleae* Fons-Colombe, Ann. Soc. Ent. Fr. 9:111.
- 1848 *Euphyllura oleae* Förster, Verh. natur. Ver. preuss. Rhein. 5:93.
- 1857 *Euphyllura olivina* Costa, Degl'insetti che attaccano l'olivo, etc. 35-42 [*fide*  
 Aulmann].
- 1861 *Euphyllura oleae* Flor, Bull. Soc. Imp. Nat. Moscou 34:418, 420, 422.
- 1872 *Euphyllura oleae* Meyer-Dür, Mitt. Schw. Ent. Ges. 3:403.
- 1883 *Euphyllura olivina* Löw, Verh. zool.-bot. Ges. Wien (1882) 32:245.
- 1908 *Euphyllura olivina* Oshanin, Verz. palae. Hemip. 2:340.
- 1912 *Euphyllura olivina* Oshanin, Kat. palae. Hemip. 126.
- 1913 *Euphyllura olivina* Aulmann, Psy. Cat. 67.
- 1935 *Euphyllura olivina* Haupt, Tierw. Mittel. 4, 3:227.

Length to tip of folded wings 2 mm.

COLOR: General color light green. Dorsum more or less embrowned.  
 Forewings dirty white with small brown spots.

STRUCTURE: Dorsum of head and thorax coarsely punctate. Head  
 broader than thorax, strongly deflexed. Vertex plane, twice as wide as  
 long, posterior margin evenly concave, discal impressions shallow. Genae  
 smoothly continuous with vertex, produced as broad, rounded, flattened  
 contiguous lobes. Antennae short,  $\frac{3}{4}$  as long as width of head, arising  
 beneath projecting edge of vertex. Eyes elongate, strongly recessive, ex-  
 tending back to mesonotum. Thorax very strongly arched. Pronotum  
 small, nearly vertical. Forewings twice as long as wide, coriaceous,  
 rugose, opaque, obliquely narrowed to rounded apex, costal margin  
 setate; basal vein (R + M + Cu) short, medio-cubital petiole and stem  
 of R of equal length, Rs long, nearly straight, curved to margin apically,  
 medial cell elongate, flaring at margin, cubital cell small, pterostigma very  
 large, as wide as medial cell, rugosity of membrane strong (the "cross  
 veins" of Enderlein). Membrane of hind wings finely setate. Legs short,  
 stout. Metatibia with several black spines apically. Proximal segment of

\* Adjective from *oliva*, L. f. noun—the olive tree.



metatarsus with two black spines. Metacoxal spurs very small, rounded.

GENITALIA: Male proctiger short, stout, straight, slightly swollen on caudal margin, sharply produced caudad apically. Forceps short, about  $\frac{1}{2}$  as long as proctiger, broadly spatulate. Female genital segment longer than rest of abdomen; dorsal valve sinuate on dorsal margin, apex blunt; ventral valve thick, upcurved to acute apex, nearly equalling dorsal.

Redescribed from three specimens from "Syra, Graecia" determined by Löw. Not known to occur in North America, it has been recorded from Spain, France, Italy, Dalmatia, Liguria (Aulmann).

*Euphyllura arbuti*\* Schwarz

1904 *Euphyllura arbuti* Schwarz, Proc. Ent. Soc. Wash. 6:235, 237-238.

1913 *Euphyllura arbuti* Aulmann, Psy. Cat. 67.

1914 *Euphyllura arbuti* Crawford, U. S. Nat. Mus., Bull. 85:117.

1917 *Euphyllura arbuti* Van Duzee, Cat. Hemip. N. Am. 802.

1921 *Platystigma arbuti* Enderlein, Zool. Anz. 52:116.

1923 *Euphyllura arbuti* Ferris and Hyatt, Can. Ent. 55:88-92 [life history, nymph figured].

1928 *Euphyllura arbuti* Ferris, Can. Ent. 60:116.

1932 *Euphyllura arbuti* Klyver, Ent. News 43:39.

Length to tip of folded wings 3.25 to 4 mm.

COLOR: General color yellow to brown. Darker on vertex and thoracic dorsum. A broad brown macula on forewings extending from base obliquely to anal margin distad of apex of clavus.

STRUCTURE: Finely punctate, glabrous, shining. Head broader than thorax, strongly deflexed. Vertex plane, twice as wide as long, posterior margin nearly straight, emarginate anteriorly over antennae, discal impressions very slight. Genae continuous with vertex, produced as truncate, contiguous lobes  $\frac{1}{4}$  as long as vertex. Antennae slender, slightly over  $\frac{2}{3}$  as long as width of head. Eyes slender and very strongly recessive, extending back to mesonotum. Thorax very strongly arched. Pronotum moderately long, straight, nearly vertical. Forewings coriaceous, rugose, semitransparent, obliquely rounded from apex of clavus to rounded apex at costa, twice as long as wide; Rs and M, including branches, very strongly sinuate, medial cell slender, sinuate, cubital small,  $R_1$  extending nearly straight to costa, no pterostigma, a slight notch in costa proximad  $R_1$ . Membrane of hind wings thickly set with minute setae.

GENITALIA: Male proctiger straight, longer than forceps. Forceps long, straight; in lateral view moderately slender, apices excavate cephalically leaving a blunt black-tipped tooth. Female genital segment shorter than rest of abdomen; dorsal valve straight, evenly tapered, subacute, longer than ventral; ventral valve straight, tapered to acute apex.

This species is represented in the material at hand by specimens from Jamesburg, Sargent, and Boulder Creek, California, and from Grants Pass and Canyonville, Oregon. Recorded from British Columbia

\* Genitive of *Arbutus*—the generic name of the host plant.

by Klyver. Its host plant is madrone, *Arbutus menziesii*. Ferris and Hyatt discuss the life history and habits in detail. The nymphs live in waxen cells, usually under scales of the bark. Breeding apparently occurs throughout the year.

TYPE, male, No. 8145 United States National Museum, Santa Cruz County, California, Koebele.

Type examined.

*Euphyllura arbuticola*\* Crawford

1914 *Euphyllura arbuticola* Crawford, U. S. Nat. Mus., Bull. 85:118.

1917 *Euphyllura arbuticola* Van Duzee, Cat. Hemip. N. Am. 802.

1921 *Platystigma arbuticola* Enderlein, Zool. Anz. 52:116.

"This species resembles very closely *arbuti* in most respects, including size and general color, but differs in the color of the forewing, being uniformly darker brown and not bicolored, with sometimes a lighter area across the base; the venter is darker than in *arbuti*. Body a little more rugose. Genal lobes shorter, and more squarely truncate; antennae slightly shorter. Head and thorax similar. Wings somewhat larger, thicker, more rugose; veins even more sinuate.

"The chief difference is in the male genitalia; anal valve stouter, relatively shorter; forceps distinctly thicker, without apical emargination on anterior edge, and with a distinct tooth on posterior edge inside about  $\frac{1}{3}$  the length from apex, broadly rounded at apex.

"Described from six males and four females from Chiric Mountains, Arizona (H. G. Hubbard), on *Arbutus arizonica*, in September.

"TYPE No. 18098, United States National Museum."—Crawford.

One female which is apparently this species is at hand from the Huachuca Mountains, Arizona, Aug. 22. From it I add the following: Antennae thicker than in *arbuti*. Eyes much smaller, scarcely recessive, not covering prothorax laterally. Forewing not as elongate and slender apically.

Type examined.

*Euphyllura arctostaphyli*† Schwarz

(Figs. 131, 132, 133)

1904 *Euphyllura arctostaphyli* Schwarz, Proc. Ent. Soc. Wash. 6:234-236.

1918 *Euphyllura arctostaphyli* Aulmann, Psy. Cat. 67.

1914 *Euphyllura arctostaphyli* Crawford, U. S. Nat. Mus., Bull. 85:116.

1917 *Euphyllura arctostaphyli* Van Duzee, Cat. Hemip. N. Am. 802.

1921 *Platystigma arctostaphyli* Enderlein, Zool. Anz. 52:116.

1928 *Euphyllura arctostaphyli* Ferris, Can. Ent. 60:116.

1930 *Euphyllura arctostaphyli* Klyver, Proc. Ent. Soc. Wash. 32:153-160.

1931 *Euphyllura arctostaphyli* Martin, Jour. Kans. Ent. Soc. 4:69.

1932 *Euphyllura arctostaphyli* Klyver, Ent. News 43:38.

1932 *Euphyllura arctostaphyli* Klyver, Pan-Pac. Ent. 8:15.

\* From *Arbutus*—the host plant + *cola*—inhabitant.

† Genitive of *Arctostaphylos*—the generic name of the host plant.

Length to tip of folded wings 2.0 to 3.5 mm.

**COLOR:** General color reddish to reddish brown, variable from light to very dark. Legs lighter to yellowish. Forewings generally brownish, veins red. Entire body punctate, with more or less short pubescence.

**STRUCTURE:** Head large, broad, as broad as thorax or slightly broader, strongly deflexed. Vertex plane, nearly straight-margined posteriorly, very deeply emarginate anteriorly over insertion of antennae, forming a tubercle next the eyes, nearly twice as wide as long, discal impressions slight. Genal processes continuous with vertex, short, very broad, roundly truncate, contiguous. Antennae distinctly shorter than width of head,  $\frac{2}{3}$  as long or more. Thorax broad, very strongly arched. Pronotum sharply descending anteriorly. Forewings about twice as long as wide, thickened, coriaceous, somewhat rugose, surface very rough, somewhat rhomboidal, a more or less prominent notch on costal margin opposite furcation of R; cubital petiole longer than R, Rs moderately long, straight, turned to costa, marginal cells large, medial broadly flaring, branches of media slightly sinuate, R<sub>1</sub> angling, indistinct near costa, no definite pterostigma. Hind wings thickly set with minute setae.

**GENITALIA:** Male proctiger nearly straight, slightly swollen, apex slightly produced caudad. Forceps nearly as long as proctiger, spatulate, enlarged apically; in caudal view slender, slightly arched, apices touching. Female genital segment shorter than rest of abdomen; dorsal valve slender apically, nearly straight to blunt apex; ventral valve nearly as long as dorsal, upturned, acute.

This species is very abundant on several species of manzanita (*Arctostaphylos*) in the western part of North America. It shows a great deal of variation in most characters. Schwarz (1904) named the variety *niveipennis* which was raised to specific rank by Klyver in 1930 after a detailed study of both forms. He describes and figures the principal differences. Martin in 1931 added two more to the list of named variations. These four forms can be quite easily separated in most instances. I am not convinced that they represent distinct species, however, but I believe it will be less confusing to retain the names until such time as some careful biological work shall determine the status of this complex.

In 1920 Crawford named the color variety *E. arctostaphyli bifasciata* which differs from the typical form solely in color and is evidently a true color variety.

Specimens are at hand from numerous localities in California, Oregon, Washington, Arizona, Colorado, New Mexico, Montana, and Mafeking, Manitoba. It is also recorded from Wyoming by Crawford, and from Nevada and British Columbia by Klyver.

Specimens at hand are from various species of *Arctostaphylos*: *A. pungens* H. B. K., *A. tomentosa* Pur., *A. patula* Greene, *A. montana* East, *A. glauca* Lindl., *A. canescens* East, and *A. viscida* Parry.

**TYPE** No. 8143 United States National Museum, several specimens on one pin, Placer County, California, Koebele.

Types examined.

*Euphyllura arctostaphyli* var. *bifasciata*\* Crawford

1920 *Euphyllura arctostaphyli* var. *bifasciata* Crawford, Ent. News 31:13.

Similar to species except forewings with two white areas, one a broad band across wing basally, the other more irregular, oblique, near apex, not extending entirely across the wing to anal margin.

From the material at hand this pattern variation seems to occur ubiquitously with the typically colored individuals.

TYPE, female, Placer County, California, August 24, 1917, W. M. Giffard, No. 463 California Academy of Sciences (Crawford).

*Euphyllura niveipennis*† Schwarz

(Fig. 134)

1904 *Euphyllura arctostaphyli niveipennis* Schwarz, Proc. Ent. Soc. Wash. 6:235, 236-237.

1913 *Euphyllura arctostaphyli niveipennis* Aulmann, Psy. Cat. 67.

1914 *Euphyllura arctostaphyli neveipennis* Crawford, U. S. Nat. Mus., Bull. 85:117.

1917 *Euphyllura arctostaphyli niveipennis* Van Duzee, Cat. Hemip. N. Am. 802.

1930 *Euphyllura neveipennis* Klyver, Proc. Ent. Soc. Wash. 32:153-160.

1931 *Euphyllura neveipennis* Martin, Jour. Kans. Ent. Soc. 4:69.

1932 *Euphyllura neveipennis* Klyver, Ent. News 43:38.

Similar to *E. arctostaphyli*, differing in the following characters: forewings snowy white, pulverulent, due to what appears to be a loose wax deposit (Klyver, 1930, states that it is "small colorless chitinated plates"), often a few bright red spots on margin; female genital segment distinctly shorter, valves equal in length, dorsal valve not slender and attenuate but more nearly acute and slightly downcurved apically, entire segment thickly set with short fine setae of equal length, giving it a very distinctive appearance; male forceps broader from base, not enlarged apically, more tapered apically in lateral view and slightly curved cephalad.

For an exhaustive discussion of the differences between these two forms, see Klyver, 1930. In the large series of *arctostaphyli* at hand the range of size is so great that it includes that of *niveipennis* also.

Specimens are at hand from several localities in California, some of them from *Arctostaphylos viscida* Parry.

TYPES, 12 specimens on 1 pin, No. 8144 United States National Museum, Placer County, California, Koebele.

Types examined.

*Euphyllura pruinosa*‡ Martin

1931 *Euphyllura pruinosa* Martin, Jour. Kans. Ent. Soc. 4:69.

Similar to *E. arctostaphyli* except as follows: More pubescent, entire body including forewings more or less covered with flaky white wax deposit apparently secreted by the setae which cover the body; general color of body light yellow, with scattered red punctations, medio-anterior

\* From *bi*, L. prefix—two + *fasciatus*, L. (p. part of *fascio*)—banded.

† From *niveus* -a -um, L. adj.—snowy + *pennis*, L. irr. noun—wing.

‡ *pruinosa* -a -um, L. adj.—frosty.

portion of prescutum and four broad longitudinal stripes on scutum brown, forewings white with numerous very small brown spots, slightly more dense apically; female genitalia similar to *arctostaphyli*; male more like *niveipennis*, forceps even broader in lateral view.

Specimens are at hand from numerous localities in California taken on *Arctostaphylos pungens*, H. B. K., *A. glauca* Lindl., and *A. tomentosa* Pur.

It should be noted that although this form is very distinct in appearance from *arctostaphyli* the differences are almost solely in color, greater pubescence, and presence of a prominent waxy deposit.

TYPE, male, San Diego County, California, in Snow Collection, University of Kansas.

### *Euphyllura bicolor*\* Martin

1931 *Euphyllura bicolor* Martin, Jour. Kans. Ent. Soc. 4:69, 70.

Similar to *E. arctostaphyli* from which it differs as follows: Larger (3.5 to 4.5 mm. in length); general color yellow, with small red spots, eyes and thoracic dorsum almost entirely red; forewings cream colored, opaque, (not appearing pulverulent as in *niveipennis*, and rugae of wing more apparent); medial cell very large; female genital segment longer, dorsal valve sinuate, attenuate, downcurved to blunt tip, pubescence more as in *niveipennis* but not as thick. Male genitalia as in *niveipennis*.

This form is consistently larger than the preceding three in the material at hand. The female genitalia is its most distinctive feature other than color.

Numerous specimens are before me from various localities in California, from several species of *Arctostaphylos* including *A. glauca* Lindl., *A. manzanita* Parry, *A. zacaensis* East, *A. patula* Greene, and *A. glandulosa* East.

TYPE, male, Alpine, California, in Snow Collection, University of Kansas.

### *Euphyllura separata*† n. sp.

(Figs. 149, 150, 296)

Length to tip of folded wings 2.25 to 2.75 mm.

COLOR: General color red to black. Forewings very thickly strewn with small brown spots except at tip of clavus.

STRUCTURE: Head and thorax punctate. Head and prothorax vertical. Vertex with broad discal impressions, twice as wide as long, swollen anteriorly, rounded down to anterior ocellus, and smoothly to genal processes, produced as a blunt lobe next to eyes. Genal processes very short, quadrate, scarcely contiguous, not deflexed from plane of vertex. Antennae very short, not much over  $\frac{1}{2}$  as long as width of head.

\* From bi-L. prefix—two + color -oris, L. m. noun—color.

† *separatus* -a -um, L. adj.—distinct.



Thorax very strongly arched. Prothorax straight. Prescutum strongly deflexed. Forewings slightly rhomboidal, rounded apically, rugose, thickened, not notched on costal margin, twice as long as wide; Rs straight to near apex then curved to costa, branches of media strongly divergent, straight, medial cell larger than cubital, pterostigma lacking.

GENITALIA: Male proctiger long, slightly tapering apically. Forceps spatulate, straight; in lateral view broad, narrowed apically. Female genital segment very large, much longer than rest of abdomen; dorsal valve tapering to acute, upturned apex, dorsal margin sinuate; ventral valve thick, shorter than dorsal, evenly upcurved to acute apex.

Described from 2 females and 8 males bearing the data, "10 miles west of Bend, Oregon, June 21, 1939, Gray and Schuh."

HOLOTYPE, female, ALLOTYPE, male, and paratypes in the collection of Oregon State College. Paratypes in author's collection.

### Genus *Pachypsylla*\* Riley

1861 *Psylla* Osten-Sacken (pro parte), Ent. Zeit. 22:422.

1883 *Pachypsylla* Riley, Can. Ent. 15:157.

1885 *Pachypsylla* Riley, Proc. Biol. Soc. Wash. 2:71.

1885 *Pachypsylla* (*Blastophysa*) Riley, Proc. Biol. Soc. Wash. 2:74.

1913 *Pachypsylla* Aulmann, Psy. Cat. 29.

1914 *Pachypsylla* Crawford, U. S. Nat. Mus., Bull. 85:108 [designates type].

1917 *Pachypsylla* Van Duzee, Cat. Hemip. N. Am. 799.

Head small, vertical. Eyes hemispherical, lateral. Ocelli large. Vertex plane or somewhat rounded anteriorly, quadrate, broader anterior to eyes than on posterior margin. Genae produced as short lobate processes, depressed strongly from plane of vertex. Antennae short, about as long as width of head. Thorax large, strongly arched. Forewings more or less rhomboidal, often opaque or semiopaque, rugose, punctate, or covered with disc-shaped cuticular thickenings, M + Cu with common base, marginal cells more or less elongate, pterostigma present, small to moderate size. Hind wings with prominent venation, at least basal vein (R + M + Cu) heavily sclerotized. Hind tibia without basal spur, with several small black spurs apically. Basal segment of metatarsus with two black claws. Metacoxal spurs, large, stout, blunt.

Logotype: *Pachypsylla venusta* Osten-Sacken.

Riley in 1883 mentioned, in a short article on the galls of *Celtis*, that these insects belonged to a new genus which in a paper he had prepared was called *Pachypsylla*. He then proceeded to give a short characterization of the genus. The aforementioned paper did not appear until two years later.

The genus is composed entirely of gall-forming species which inhabit *Celtis* spp., the hackberries. It is known only from North America. Boselli (1929b) described the nymph of an unknown species of psyllid forming galls on *Celtis sinensis* in China which may belong to *Pachypsylla*.

The subgenus *Blastophysa* was erected by Riley for *P. celtidis-*

\* From *pachys*, Gr. adj.—thick, large + *psylla*.



*gemma*. The differences between it and the other species are insufficient to warrant any such distinction, however.

### Key to the Species of *Pachypsylla*

1. Head and thoracic dorsum with short stiff pubescence, not shining; marginal cells of forewings very elongate; forewings not rugose. . . . . 2.  
Head and thorax appearing glabrous, shining (often with sparse, minute pubescence); marginal cells less elongate, broad; forewings more or less rugose. . . . . 4.
2. Large species (5.5 to 6 mm.). . . . . *venusta* p. 534.  
Smaller species (4 mm. or less). . . . . 3.
3. Length to tip of folded wings 3 to 4 mm. . . . . *celtidis-mamma* p. 536.  
Length to tip of folded wings 2.5 mm. or less. . . . . *celtidis-vesicula* p. 538.
4. Forewings uniformly brown. . . . . *celtidis-gemma* p. 539.  
Forewings maculate. . . . . 5.
5. Branches of media sinuate. . . . . *celtidis-inteneris* p. 540.  
Branches of media not sinuate. . . . . 6.
6. Forewings finely mottled apically. . . . . *dubia* p. 541.  
Forewings with large maculae (sometimes finely mottled also). . . . . *pallida* p. 541.

### *Pachypsylla venusta*\* (Osten-Sacken)

(Figs. 137, 138, 139, 140)

- 1861 *Psylla venusta* Osten-Sacken, Ent. Zeit. 22:422.  
 1876 *Psylla celtidis-grandis* Riley, Johnson's Univ. Cycl. (gall) [*fide* Riley]  
 1883 *Pachypsylla venusta* Riley, Can. Ent. 15:157 (gall only).  
 1883 *Psylla venusta* Fyles, Can. Ent. 15:84, 199.  
 1885 *Pachypsylla venusta* Riley, Proc. Biol. Soc. Wash. 2:70, 72 [describes].  
 1885 *Pachypsylla venusta* Riley, 5th Rept. U. S. Ent. Comm. 615-617.  
 1894 *Pachypsylla venusta* Mally, Proc. Ia. Acad. Sci., 1, 4:137.  
 1895 *Pachypsylla venusta* Mally, Proc. Ia. Acad. Sci. 2:153.  
 1912 *Pachypsylla tridentata* Patch, Me. Agr. Exp. Sta., Bull. 202:224.  
 1913 *Pachypsylla venusta* Aulmann, Psy. Cat. 30.  
 1914 *Pachypsylla venusta* Crawford, U. S. Nat. Mus., Bull. 85:109.  
 1917 *Pachypsylla venusta* Van Duzee, Cat. Hemip. N. Am. 799.  
 1923 *Pachypsylla venusta* Patch, Hemip. Conn. 247.  
 1926 *Pachypsylla venusta* Ferris, Can. Ent. 58:13-15 [describes and figs. nymph].  
 1929 *Pachypsylla venusta* Boselli, Boll. Lab. Zool. Gen. e Agr. Port. 22:204-218.  
 1932 *Pachypsylla venusta* Klyver, Ent. News 43:38.  
 1938 *Pachypsylla venusta* Brimley, Ins. N. C. 104.  
 1938 *Pachypsylla venusta* Caldwell, Ohio Biol. Surv., Bull. 34:255.

Length to tip of folded wings 5 to 5.5 mm.

**COLOR:** General color tawny with numerous black markings, latter often so extensive that general color black, markings tawny would be more accurate. Dorsum of thorax longitudinally striped. Forewings whitish, maculate in well-colored specimens with black as follows: a broad band of small spots across apical third becoming more dense apically, a clear rectangular area on margin between the apices of each pair of veins; small single maculae at base of pterostigma, along basal vein and R, at furcation of M and Cu and two or three on anal margin. Antennae with dark annulus on apex of each segment.

**STRUCTURE:** Entire body punctate, head coarsely. Head much narrower than thorax, vertical. Eyes large, hemispherical. Vertex plane,

\**Venustus* -a -m, L. adj.—beautiful.

quadrate, emarginate posteriorly, rounded to genae anteriorly,  $\frac{3}{4}$  as long as wide, discal impressions small, foveate. Genal processes lobate, strongly divergent, heavily pubescent, about  $\frac{1}{3}$  as long as vertex, much depressed from plane of vertex but parallel to it. Antennae slightly longer than width of head. Thorax very strongly arched, very short sparse pubescence dorsally. Pronotum strongly descending, nearly vertical, long. Prescutum large, descending anteriorly. Forewings large, hyaline, rhomboidal, slightly over  $2\frac{1}{2}$  times as long as wide, membrane thickly set with minute setae, veins biserially set with small setae; Rs long, slightly sinuate, marginal cells elongate, cubital larger than medial,  $M + Cu$   $\frac{1}{2}$  as long as R, pterostigma of moderate size. Hind wings nearly equalling forewings, thickly set with minute setae, venation prominent,  $R + M + Cu$  heavily sclerotized. Legs large, heavily pubescent, hind tibia with small basal tubercle.

**GENITALIA:** Male proctiger short, stout, roundly produced caudad, near apex sharply emarginate, apical epiphysis thus formed sharply flexed caudad. Forceps in lateral view broad basally, strongly narrowed then slightly tapering to subacute apices; in caudal view moderately broad basally, tapering to incurved subacute tips. Female genital segment very large, longer than rest of abdomen; dorsal valve straight, apical third slender, roughened, apex acute, upturned; ventral valve roughened toward apex, gently upturned, acute.

Baron Osten-Sacken in an article on the Galls of North America describes the galls he found on the leaf petioles of *Celtis occidentalis* and then says, "I reared therefrom a beautiful large *Psylla*, (*P. venusta* n. sp.) with black-flecked wings. The peculiar form of the apex of the metasternum and of the wing veins will no doubt make it necessary to erect a new genus for this species." Since this mention of the insect constitutes a description under the rules of nomenclature it is fortunate that he was dealing with this species since the gall is quite typical in this instance.

The galls are large (ave. 1 to 1.5 cm. in diameter), more or less spherical, not completely closed on one side and form on the leaf petioles. They remain attached to the tree usually, the mature insects emerging in the spring when the temperature becomes sufficiently high. They may be brought out during the winter by bringing them into a warm room. The last stadium nymph crawls from the gall and emerges as the adult very shortly thereafter. The galls are polythalamous.

Known from Iowa, Kansas, Colorado, Texas, New Mexico, Ohio, Mississippi, Tennessee, North Carolina, New Jersey, and Connecticut. It is undoubtedly much more widespread throughout the range of its host.

*Pachypsylla celtidis-mamma*\* (Fletcher)

(Fig. 258)

- 1876 *Psylla celtidis-mamma* Riley, Johnson's Univ. Cycl. (gall) [fide Riley, Can. Ent. 15:157].
- 1883 *Psylla celtidis-mamma* Fletcher, Rept. Ent. Soc. Ont. 1882, 13th:79-80 [reprint of Riley 1876 and describes insect].
- 1883 *Psylla celtidis-mamma* Fletcher, Can. Ent. 15:40.
- 1883 *Pachypsylla celtidis-mamma* Riley, Can. Ent. 15:157-158 [gall].
- 1883 *P. celtidis-mamma* Fyles, Can. Ent. 15:199.
- 1885 *Pachypsylla celtidis-mamma* Riley, Proc. Biol. Soc. Wash. 2:73 [detailed desc.].
- 1890 *Pachypsylla c. mamma* Riley, 5th Rept. U. S. Ent. Comm. 615, 616, 619.
- 1894 *Pachypsylla celtidis-mamma* Mally, Proc. Ia. Acad. Sci. 1, 4:131-137.
- 1895 *Pachypsylla celtidis-mamma* Mally, Proc. Ia. Acad. Sci. 2:154.
- 1910 *Pachypsylla rohweri* Cockerell, Ent. News 21:180.
- 1910 *Pachypsylla celtidis-mammae* Stough, Kans. Univ. Sci. Bull. 5, No. 9:121-165, pt. XXVI-XXXV [morphology].
- 1913 *Pachypsylla celtidis-mamma* Aulmann, Psy. Cat. 30.
- 1914 *Pachypsylla c. -mamma* Crawford, U. S. Nat. Mus., Bull. 85:110.
- 1917 *Pachypsylla celtidis-mamma* Van Duzee, Cat. Hemip. N. Am. 800.
- 1923 *Pachypsylla celtidis-mamma* Patch, Hemip. Conn. 247.
- 1929 *Pachypsylla celtidis-mamma* Boselli, Boll. Lab. Zool. Gen. e Agr. Port. 22:204-218.
- 1932 *Pachypsylla c.-mamma* Klyver, Ent. News 43:38.
- 1938 *Pachypsylla celtidis-mamma* Caldwell, Ohio Biol. Surv., Bull. 34:257.

Length to tip of folded wings 3 to 4 mm.

COLOR: General color dull brownish yellow with many variable black and brown markings. Antennae with dark annulus apically on each segment. Forewings white with numerous small round brown spots usually more or less fused each side of an oblique subapical band almost free of them. Markings extremely variable, especially on the forewing. Very commonly a large irregular macula appears centrally, occasionally this is very sharp and dark with the remainder of the wing almost immaculate.

STRUCTURE: Entire body punctate with short pubescence, most prominently on head and thoracic dorsum. Head narrower than thorax, vertical. Vertex plane, nearly quadrate,  $\frac{2}{3}$  as long as wide, discal impressions broad, shallow. Genal processes depressed from plane of vertex but parallel to it, short, strongly divergent, bluntly rounded,  $\frac{1}{3}$  as long as vertex, heavily pubescent. Antennae about  $\frac{4}{5}$  as long as width of head, arising far down on head. Thorax strongly arched. Pronotum nearly vertical. Prescutum large. Forewings  $2\frac{1}{2}$  times as long as wide, very slightly rhomboidal, surface covered with minute circular plates, veins very prominent, biserially setate; Rs long, somewhat sinuate, marginal cells very elongate, equal in length, medial broader, M + Cu very short,  $\frac{1}{3}$  as long as R, pterostigma large, yellowish. Legs long.

GENITALIA: Entire genital segment of male heavily pubescent. Proctiger stout, slightly enlarged from base to near apex then sharply emarginate on caudal margin, a large apical epiphysis thus formed, flexed

\* Genitive of *Celtis* the generic name of its host plant + *mamma* -ae, L. f. noun—breast (a reference to the shape of the galls formed by this insect). The form of this and the following three names is extremely poor. They are basically trinomial; however, as they were used as binomials, they must stand.

caudad. Forceps stout; in lateral view anterior margin somewhat sinuate, narrowed apically to subacute apices; in caudal view moderately stout basally, arched and tapered to acute apices. Female genital segment shorter than rest of abdomen, slender; dorsal valve straight, attenuate apically, tip acute; ventral valve shorter than dorsal, slightly, evenly, upcurved to acute apex.

The galls formed by this species occur on the leaves of hackberry, developing into a more or less mammiform growth on the underside of the leaf. On the upper surface of the leaf a depression forms, cupping down into the gall. The shape of the gall itself is quite variable, often with a nipple-like tip, sometimes conical, glabrous or pubescent, etc. Usually they are monothalamous.

The adults emerge in the fall, overwinter in crevices of bark, etc.; early in the spring they fly to the twigs, and after mating, the females begin to deposit eggs about as soon as the leaves begin to appear. The nymphs feed on the lower side of the leaves and are soon enclosed in the gall. There is but one generation per year, the nymphs reaching maturity in September.

In 1876 Riley in an article on "Galls" in Johnson's Universal Cyclopaedia (which I have not seen) discussed the gall formation of this entire group in a very general way. Fletcher (1883) purports to "reproduce this in full," but his excerpt does not contain the name *celtidis-mamma* at all. However, Riley (1883) credits the use of the name to that article. Fletcher in the above-mentioned article unfortunately proceeds to discuss the coloration and some of the structure of the insect and thus becomes the author of the species since Riley's original use of the name is an utter *nomen nudum*, and his detailed description which he headed "n. sp." did not appear until 1885. Fletcher mentions no specific specimens and undoubtedly kept none, so Riley's designated types in the United States National Museum stand as the type specimens. There are numerous cotypes in the series on four pins, the type number being 657.

The type of *Pachypsylla rohweri* Cockerell (No. 18476) is in the National Museum and is in my opinion identical with *celtidis-mamma*.

The variation in this species is quite marked, especially the coloration, most markedly the wing pattern, so much so that when first encountered it appears that several species must be present. Fortunately, the insect is very abundant throughout its range and thus almost all of those who have dabbled in the group have come to the conclusion that the variants are so numerous and diverse that they are indistinguishable and inconstant.

Riley, apparently assuming that the shape of a gall was an extremely accurate and highly constant specific character (even more so than the structure of the insect) proposed names for a species of *Pachypsylla* for each different shape of gall that he found. With these names he described the galls in detail but made no mention whatsoever of the insects. In a preliminary statement, however, he said "the yet undescribed species are all so closely allied to *P. c-mamma* that they can only

be distinguished with difficulty." Elsewhere (Can. Ent. 15:158) he says of one of them "*P. c-mamma* so closely resembles another species (*P. c-cucurbita* M. S. mihi), however, that without the galls it would be difficult, if not impossible to separate them—a not uncommon occurrence among gall-making species." Anyone rearing these insects from the galls and not blinded by the above assumption of infallible gall specificity must soon come to the conclusions reached by Mally (1849) that, "the shape and size of the gall is not at all constant . . . It was found that *P. c-mamma* occurred in all the different variations, thus showing that these variations are not of specific importance." Fortunately, the series of names proposed by Riley stand as *nomina nuda*. Some few of them have cluttered up the literature of galls, however, and do until the present time.

This species frequently becomes a nuisance in the house in autumn when seeking hibernation quarters. Large numbers often collect on the screens, which barrier they readily penetrate and move into the household to hide for the winter. Typically, they seek shelter in the rough bark of the hackberry and other trees.

I have seen specimens of this very abundant animal from, or definite records are available of its occurrence in, the following states and provinces: Colorado, Texas, Arizona, Utah, Oklahoma, Kansas, Nebraska, Iowa, Minnesota, Illinois, Indiana, Ohio, North Carolina, New Jersey, New York, Connecticut, and Ontario.

It undoubtedly occurs, however, throughout the range of its host species, hackberry (*Celtis occidentalis* L.).

#### *Pachypsylla celtidis-vesicula*\* Crawford

- 1890 *Pachypsylla celtidis-vesiculum* Riley, 5th Rept. U. S. Ent. Comm. 618 [gall].  
 1895 *Pachypsylla celtidis-vesiculum* Mally, Proc. Ia. Acad. Sci. 2:154 [lists].  
 1913 *Pachypsylla celtidis-vesiculum* Aulmann, Psy. Cat. 30 [lists].  
 1914 *Pachypsylla c.-vesiculum* Crawford, U. S. Nat. Mus., Bull. 85:112 [describes].  
 1917 *Pachypsylla celtidis-vesiculum* Van Duzee, Cat. Hemip. N. Am. 801.  
 1923 *Pachypsylla celtidis-vesiculum* Patch, Hemip. Conn. 247.  
 1938 *Pachypsylla celtidis-vesiculum* Caldwell, Ohio Biol. Surv., Bull. 34:259.

Length to tip of folded wings 2 to 2.5 mm.

This form is very similar to *celtidis-mamma* but seems to be a distinct species. It is distinctly smaller; the wing pattern is often more or less diffuse. Other minor differences have been noted by Crawford and Caldwell, none of which will hold when a large series from various localities is studied. The sudden narrowing midway of the ventral valve of the female genital segment is the most constant of these.

The gall formed on the leaves of the hackberry is of a quite different type from that of *celtidis-mamma*; it is blister-like and more prominent on the upper than on the lower surface. Very many galls are frequently found on the same leaf, and they are found on the same leaf

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\* *vesicula* -ae, L. f. noun—little blister (the improper ending used by Riley and others is here corrected).



with *celtidis-mamma* galls. This species is extremely abundant. It overwinters in the adult stage as does its relative and in company with it sometimes becomes a household nuisance in the fall.

All uses of the name *cestidis-vesiculum* until 1914 are *nomina nuda*. Although the gall was often described, no one mentioned the insect until Crawford discussed it briefly in his monograph.

It is known from Iowa, Nebraska, Kansas, Oklahoma, Arizona, Louisiana, Ohio, New York, New Jersey, and Connecticut. It doubtlessly occurs throughout the range of its host (*Celtis*).

No type has ever been designated; the cotypic series is presumably in Crawford's collection.

*Pachypsylla celtidis-gemma*\* Riley

(Fig. 259)

- 1885 *Pachypsylla* (*Blastophysa*) *c.-gemma* Riley, Proc. Biol. Soc. Wash. 2:74-75.  
 1890 *Pachypsylla c.-gemma* Riley, 5th Rept. U. S. Ent. Comm. 615, 616, 618.  
 1894 *Pachypsylla c.-gemma* Mally, Proc. Ia. Acad. Sci. 1, 4:138.  
 1895 *Pachypsylla* (*Blastophysa*) *celtidis-gemma* Mally, Proc. Ia. Acad. Sci. 2:154.  
 1913 *Pachypsylla* (*Blastophysa*) *celtidis-gemma* Aulmann, Psy. Cat. 30.  
 1914 *Pachypsylla c.-gemma* Crawford, U. S. Nat. Mus., Bull. 85:112.  
 1917 *Pachypsylla celtidis-gemma* Van Duzee, Cat. Hemip. N. Am. 801.  
 1921 *Pachypsylla celtidis-gemma*, Weiss, Can. Ent. 53:19-21.  
 1923 *Pachypsylla celtidis-gemma* Patch, Hemip. Conn. 247.  
 1938 *Pachypsylla celtidis-gemma* Caldwell, Ohio Biol. Surv., Bull. 34:255.  
 1938 *Pachypsylla celtidis-gemma* Brimley, Ins. N. C. 104.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: General color brownish yellow, vertex and legs darker, forewings evenly brown, opaque.

STRUCTURE: Head much narrower than thorax, vertical, coarsely punctate, shining. Vertex straight on posterior margin, quadrate, rounded down to genal processes anteriorly,  $\frac{2}{3}$  as long as wide, discal impressions small, foveate. Genal processes short, rounded, strongly divergent,  $\frac{1}{3}$  as long as vertex, pubescent, much depressed from plane of vertex but on nearly parallel plane. Antennae a little longer than width of head. Thorax large, very strongly arched, shining, glabrous. Pronotum nearly vertical. Prescutum large. Forewings slightly over twice as long as wide, narrowly rounded apically, costal margin slightly concave at pterostigma, rugoso-punctate, strongly convex, veins scarcely raised from surface except basally; Rs short, nearly straight, marginal cells of moderate size, equal, not extremely elongate,  $M_1$  slightly sinuate, R nearly twice as long as  $M + Cu$ , pterostigma very small. Hind wings nearly equalling forewings, thickly set with minute setae, venation prominent. Legs long, heavily pubescent.

GENITALIA: Male proctiger stout, roundly swollen caudad, with a prominent epiphysis. Forceps short; in lateral view straight, broadest basally, apically tapered to subacute tips; in caudal view stout, strongly

\* From *gemma -ae*, L. f. noun—bud (of the plant), in reference to the position of the gall.



arched to acute apices. Female genital segment slender, shorter than rest of abdomen; dorsal valve slightly upcurved, tip subacute; ventral valve evenly upcurved to acute apex, nearly as long as dorsal.

The shining head and thorax of this species and those following readily distinguish them from the preceding forms. The adults appear in the spring (April and May in Iowa), having overwintered as nymphs in the galls. The galls are formed from the axillary buds on the twigs, usually they are polythalamous. Weiss (1921) gives a detailed account of the life history.

Specimens are at hand from Maryland, New Jersey, St. Catharine's Island, Georgia, Iowa, Nebraska, Kansas, Oklahoma, and Louisiana. It is also recorded from Virginia, District of Columbia, New York, Connecticut, Ohio, and Missouri.

Numerous COTYPES (galls, nymphs, and adults), No. 658, United States National Museum.

*Pachypsylla celtidis-inteneris*\* Mally

(Fig. 260)

1894 *Pachypsylla c.-inteneris* Mally, Proc. Ia. Acad. Sci. 1, 4:138.

1895 *Pachypsylla celtidis-inteneris* Mally, Proc. Ia. Acad. Sci. 2:154.

1913 *Pachypsylla celtidis-inteneris* Aulmann, Psy. Cat. 30.

1914 *Pachypsylla inteneris* Crawford, U. S. Nat. Mus., Bull. 85:113.

1917 *Pachypsylla inteneris* Van Duzee, Cat. Hemip. N. Am. 801.

1938 *Pachypsylla unguolata* Caldwell, Ohio Biol. Surv., Bull. 34:255, 256-257.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: General color dark brown to black. Vertex and thoracic dorsum with more or less yellow, sometimes entirely yellow. Forewings hyaline except for an irregular macula usually as follows: black along pterostigma becoming dark brown and continuing around apex as a broad band onto tip of clavus, extending along Cu and basal vein, sometimes extending across to costa, leaving an isolated clear area medially, or entire basal  $\frac{2}{3}$  dark.

STRUCTURE: Head narrower than thorax, vertical. Vertex coarsely punctate, shining, with sparse minute pubescence, quadrate, strongly rounded down anteriorly, posterior margin straight,  $\frac{2}{3}$  as long as wide, discal foveae very small. Genal processes short, blunt, scarcely divergent,  $\frac{1}{3}$  as long as vertex, sparsely pubescent, strongly depressed from plane of vertex. Antennae stout, slightly longer than width of head. Thorax strongly arched, shining. Pronotum descending but not vertical. Forewings somewhat rugose (less so than in *celtidis-gemma*), shining,  $2\frac{1}{2}$  times as long as wide, rounded apically; Rs nearly straight, long, marginal cells large, equal, branches of M sinuate,  $M_1$  more strongly so, pterostigma small. Hind wings thickly set with minute setae, venation prominent. Legs large, heavily pubescent.

GENITALIA: Male proctiger in lateral view stout, straight, slightly swollen caudally, with a prominent epiphysis apically. Forceps in lateral

\* Possibly from *in*, a negative particle + *tener* -era -erum, L. adj.—tender.

view moderately broad, basally enlarged, then tapered to apices; in caudal view broad basally, arched, narrowed on lateral margins in apical  $\frac{1}{3}$  to acute apices. Female genital segment slender, shorter than rest of abdomen; dorsal valve straight, apical portion slender to subacute apex; ventral valve shorter, suddenly narrowed  $\frac{2}{3}$  of way to apex, acute.

This species is quite similar to *celtidis-gemma* from which it can be distinguished by the maculate forewings and the venation, chiefly the sinuate branches of media. The adults emerge in the spring from the galls which are located beneath the bark on the twigs or bases of the larger limbs.

The type series, three females, is in the Iowa State College Collection. A female bearing Mally's type label, reared from a gall by him, at Ames, is designated as the lectotype. When Caldwell was working with this genus in Ohio, he inquired as to the whereabouts of the type of this species. At that time Mally's specimens were hidden away where they had gone unnoticed apparently since his departure from Ames, and Caldwell was informed that none of Mally's specimens were here; he therefore proceeded with his description of *P. ungulata*. I have at hand a specimen of *ungulata*, and it is without doubt *inteneris* although much better colored than any of the types which are all somewhat teneral.

Known from Iowa, Illinois, and Ohio.

#### *Pachypsylla dubia*\* Patch

1912 *Pachypsylla dubia* Patch, Me. Agr. Exp. Sta., Bull. 202:224.

1914 *Pachypsylla dubia* Crawford, U. S. Nat. Mus., Bull. 85:113.

1917 *Pachypsylla dubia* Van Duzee, Cat. Hemip. N. Am. 801.

Crawford, who saw the types of this species, has the following to say concerning it: "I have examined a paratype of this and the following species (*pallida*), and both seem to be distinct from *c.-gemma* though closely related. The chief difference is in the mottled appearance of the forewing instead of being uniformly brown.

"Seven paratypes in the collection of Cornell University, but the locality is not given for any of them."

Miss Patch in her original description says no more—rather a little less—as she apparently had no specimens of *c.-gemma*.

There are no further records of the occurrence of this form.

#### *Pachypsylla pallida*† Patch

1912 *Pachypsylla pallida* Patch, Me. Agr. Exp. Sta., Bull. 202:225.

1914 *Pachypsylla pallida* Crawford, U. S. Nat. Mus., Bull. 85:113.

1917 *Pachypsylla pallida* Van Duzee, Cat. Hemip. N. Am. 801.

Length to tip of folded wings 3.5 mm.

COLOR: General color greenish yellow to yellowish brown. Prescutum especially of a green cast. Forewings hyaline or somewhat whitish except

\* *dubius* -a -um, L. adj.—uncertain, doubtful.

† *pallidus* -a -um, L. adj.—pale.

for dark maculae as follows: three broad transverse bands, one apical, one crossing base of medial cell, the third arising at costal angle, extending obliquely to apex of clavus, all three converging on anal margin at tip of clavus, latter two quite irregular. Pterostigma dark.

**STRUCTURE:** Head narrower than thorax, vertical. Vertex plane, coarsely punctate, shining, somewhat rounded down anteriorly, over  $\frac{1}{2}$  as long as wide, discal foveae small, prominent. Genal processes elongate, blunt, slightly pubescent, somewhat divergent, about  $\frac{1}{3}$  as long as vertex. Antennae a little longer than width of head. Thorax well arched. Pronotum nearly vertical. Prescutum large. Forewings broad, a little over twice as long as wide, finely rugose, set with minute setae, at least basally, broadly rounded; Rs short, slightly sinuate, marginal cells equal, broad, R over twice as long as M + Cu, pterostigma small, costal margin slightly concave. Hind wings thickly set with minute setae. Legs heavily pubescent.

**GENITALIA:** Male genitalia very similar to *celtidis-inteneris*. Proctiger somewhat swollen caudally, with a caudally flexed epiphysis. Forceps enlarging from moderately narrow base, then converging to subacute apices; in caudal view strongly arched, tapered to acute apices. Female genital segment long, slender, upcurved; dorsal valve slender, evenly upcurved, attenuate in apical half, apex subacute; ventral valve long but shorter than dorsal, evenly upcurved to slender, acute tip.

Numerous specimens are at hand from several localities in Arizona and New Mexico which seem undoubtedly to be this species. Two of them, from Organ Mountains, New Mexico, are accompanied by galls. The latter are on the twigs and appear to be very densely pubescent; on closer examination this pubescence seems to be a dense growth of sporangio-phores of a white fungus, completely covering the galls. There is no evidence to indicate whether this is accidental or whether there is some significance to this association.

### Genus *Tetragonocephala*\* Crawford

1914 *Tetragonocephala* Crawford, U. S. Nat. Mus., Bull. 85:108.

1917 *Tetragonocephala* Van Duzee, Cat. Hemip. N. Am. 799.

Head narrower than thorax, vertical. Vertex quadrate, smooth, rounded down anteriorly. Genae produced as lobate processes, parallel to plane of vertex. Thorax very strongly arched. Pronotum long, vertical. Wings submembranous, elongate-ovate, marginal cells elongate, pterostigma lacking, M and Cu petiolate. A small tubercle on base of metatibia, basal segment of metatarsus without black spines. Metacoxal spurs long, straight, slender.

Orthotype: *Tetragonocephala flava* Crawford.

Placed in the subfamily *Psyllinae* by Crawford, this genus seems to be related to *Pachypsylla*. One of the cardinal characters of this subfamily

\* From *tetragonon* -i, Gr. n. noun—quadrangle + *cephala* -ae, Gr. f. noun—head.

is, however, lacking. The basal segment of the metatarsus is without spines. At least for the present, however, it is left in this subfamily.

*Tetragonocephala flava*\* Crawford

(Figs. 135, 136, 151, 152)

1914 *Tetragonocephala flava* Crawford, U. S. Nat. Mus., Bull. 85:108.

1917 *Tetragonocephala flava* Van Duzee, Cat. Hemip. N. Am. 799.

1926 *Tetragonocephala flava* (??) Ferris, Can. Ent. 58:16 [describes nymph of unknown sp.].

Length to tip of folded wings 3.75 to 4.25 mm.

**COLOR:** General color of newly emerged individuals green, more mature specimens yellow to brown, darkest dorsally. Six round black spots on scutum, one on scutellum. Membrane of wings milky, veins yellow.

**STRUCTURE:** Head vertical. Vertex flat, rectangular. Genal processes large, blunt,  $\frac{1}{2}$  as long as vertex. Antennae slender,  $1\frac{1}{4}$  times as long as width of head. Thorax strongly arched. Pronotum large, almost vertical, extending down laterally beyond antennal insertion. Forewings rounded, tapering somewhat apically, about  $2\frac{1}{2}$  times as long as wide; no pterostigma, furcation of media about even with furcation of cubitus, medial cell very long. Legs long. Proximal segment of metatarsus without claws. Small tubercle at base of hind tibia.

**GENITALIA:** Male proctiger long and slender, almost twice as long as forceps, slightly swollen in lateral view, anus borne on long, prominent epiphysis. Forceps in lateral view broad basally, narrowed and curved caudad to blunt, black-tipped apices; in caudal view broad, strongly arched to convergent, sharp, black apices; tips in dorsal view seem to be broad and flattened. Female genital segment short; ventral valve very small, broadly produced apically; dorsal valve large, deeply concave caudally as if collapsed (six females are at hand and all present this same peculiar appearance), margins of depression with many long, curling, hairlike setae; ovipositor pointing ventrad.

Described from one male and four females from Brownsville, Texas, one female from the Santa Rita Mountains, Arizona, and a pair from Mexico intercepted at Brownsville on incoming produce. The type specimen is a female rather than a male as stated by Crawford. The male from Brownsville, Texas, collected June 29, 1938, R. H. Beamer, is designated the allotype. It is deposited in the Snow Collection at the University of Kansas.

**TYPE**, female, No. 18096 United States National Museum, Brownsville, Texas.

Type examined.

\* *flavus* -a -um, L. adj.—yellow.

Genus *Spanioneura*\* Förster

- 1848 *Spanioneura* Förster, Verh. natur. Ver. preuss. Rhein. 5:94.  
 1876 *Spanioneura* Scott, Trans. Ent. Soc. London 1876:527, 550.  
 1878 *Spanioneura* Löw, Verh. zool.-bot. Ges. Wien 28:608.  
 1912 *Spanioneura* Oshanin, Kat. paläa. Hemip. 128.  
 1913 *Spanioneura* Aulmann, Psy. Cat. 32.  
 1935 *Spanioneura* Haupt, Tierw. Mittel 4, 3:231.

The principal points of distinction between this genus and *Psylla* are the shape of the forewings and the recessive eyes. The forewings are strongly narrowed apically, almost rhomboidal, Rs terminating at apex.

Haplotype: *Spanioneura fonscolombii* Förster.

*Spanioneura fonscolombii*† Förster

(Fig. 261)

- 1848 *Spanioneura fonscolombii* Förster, Verh. natur. Ver. preuss. Rhein. 5:94.  
 1872 *Spanioneura fonscolombii* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:403.  
 1876 *Spanioneura fonscolombii* Scott, Trans. Ent. Soc. London 1876:550.  
 1908 *Spanioneura fonscolombii* Oshanin, Verz. palae. Hemip. 2:365.  
 1913 *Spanioneura fonscolombii* Aulmann, Psy. Cat. 32.  
 1916 *Spanioneura fonscolombii* Britton, Conn. Agr. Exp. Sta., Rept. 39:186.  
 1923 *Spanioneura fonscolombii* Patch, Hemip. Conn. 247.  
 1935 *Spanioneura fonscolombii* Haupt, Tierw. Mittel. 4, 3:240.

Length to tip of folded wings 3.5 mm.

STRUCTURE: Head somewhat narrower than thorax. Vertex  $\frac{2}{3}$  as long as wide, posterior margin excavate. Genal processes long, conical, scarcely divergent, as long as vertex. Antennae slender, slightly longer than width of head. Thorax moderately arched. Forewings long, nearly 3 times as long as wide, strongly narrowed apically; Rs long, curved, extending to apex, marginal cells large, elongate, prominent radular areas on margin in cubital cell, between  $M_1$  and  $Cu_1$ , in medial cell and between Rs and  $M_1$ , pterostigma prominent. Hind wings nearly equalling forewings. Legs stout. Hind tibia with small basal spur.

GENITALIA: Female genital segment as long as rest of abdomen, straight; dorsal valve somewhat attenuate, radulate apically, apex sharp dorsally, curved ventrally; ventral valve much shorter than dorsal, slightly upturned apically, apex acute.

This species was reported by Britton (1916) as occurring on Box (*Buxus*), its host plant, in Connecticut. Four specimens (2 males, 2 females) from this series are in the Maine Agricultural Experiment Station Collection. These I have seen. They are mounted in balsam so that a complete description is impossible. No further records of its occurrence in North America are known. No adequate description and only fragmentary drawings are available in the literature.

Outside of North America it has been reported from France, Germany, and England.

\* From *spanios*, Gr. adj.—scarce + *neuron* -i, Gr. n. noun—nerve.

† Named in honor of de Fons-Colombe, a French entomologist.





### SUBFAMILY TRIOZINAE LÖW

- 1879 *Triozinae* Löw, Verh. zool.-bot. Ges. Wien 28:605, 609.  
 1886 *Triozaria* Puton, Cat. Hém. Faune Palea. 93.  
 1896 *Triozidae* Edwards, Hemip.-Homop. Br. Is. 227, 251.  
 1908 *Triozinae* Kuwayama, Trans. Sapp. Nat. Hist. Soc. 3:53.  
 1908 *Triozaria* Oshanin, Verz. palae. Hemip. 2:369.  
 1910 *Triozinae* Crawford, Pom. Coll. Jour. Ent. 2:228.  
 1911 *Triozinae* Crawford, Pom. Coll. Jour. Ent. 3:347, 422.  
 1912 *Triozaria* Oshanin, Kat. paläa. Hemip. 128.  
 1913 *Triozinae* Aulmann, Psy. Cat. 36.  
 1914 *Triozinae* Crawford, U. S. Nat. Mus., Bull. 85:18, 64.  
 1917 *Triozinae* Van Duzee, Cat. Hemip. N. Am. 791.

Head more or less deflexed, usually small and narrower than thorax. Vertex usually sharply margined, not flat. Genae produced as usually conical processes or somewhat swollen, more or less pubescent. Frons covered by genae except small portion bearing median ocellus. Eyes hemispherical. Antennae ten-segmented, slender. Thorax strongly arched usually (not in *Leuronota*). Forewings membranous, hyaline, typically angulate apically, sometimes narrowly rounded, radius, media and cubitus arising from basal vein ( $R + M + Cu$ ) at same point or very nearly so (*Hemitrioza* and *Ceropsylla*), no pterostigma, usually with three radular areas on margin, between branches of  $M$ , between  $M_1$  and  $Cu_1$  and between branches of  $Cu$ . Caudal metacoxal spurs present, anteriorly metacoxa often developed as spinose or flattened process. Metatibia usually with basal spur or serrate carina, with three or four apical spines, one on outer (lateral) margin and either two or three on inner (mesal) margin. Basal segment of metatarsus without black spines. Male proctiger usually with caudal lobes.

Type genus: *Trioza* Förster.

This subfamily is characterized chiefly by the shape of the forewings, the absence of a medial-cubital petiole, and the lack of clawlike spines on the basal segment of the metatarsus.

A few of the species are gall-forming, but the majority are free-living and somewhat active as nymphs. The latter secrete more or less wax and honeydew. They are characterized by a fringe of wax-secreting setae (sectasetae) on the margin and by the shape of the wing pads, the margins of which are almost continuous with those of the head and abdomen.

Secretion of wax is not entirely limited to the nymphal stages as many of the adults produce small quantities. This is often quite noticeable as a white band on the first abdominal tergite; this white band is very marked in some species, *Trioza rubra* and *Paratrioza cockerelli*, for example.



KEY TO THE GENERA OF *Trioziinae*

1. Radius, media, and cubitus arising from basal vein at same point. . . . . 2.  
    Radius, media, and cubitus not arising at same point, radius and media or media  
    and cubitus with a short common petiole. . . . . 8.
2. Thorax scarcely arched; pronotum long, flat, a prominent medial epiphysis on  
    cephalic margin. . . . . **Leuronota** p. 598.  
    Thorax well arched; pronotum shorter, descending cephalad, usually depressed  
    below vertex and prescutum, without an epiphysis. . . . . 3.
3. Head narrower than thorax. . . . . 4.  
    Head as broad as thorax or broader. . . . . 7.
4. Vertex smooth, rounded, no anterior margin. . . . . **Levidea** p. 604.  
    Vertex not perfectly smooth and rounded, anterior margin more or less abrupt. . . . . 5.
5. Genae produced as usually conical processes at least moderately long (usually  $\frac{1}{2}$   
    as long as vertex or longer) . . . . . **Trioza** p. 546.  
    Genal processes, if present, very short, conical or padlike, sometimes lacking, or  
    genae smoothly, spherically swollen. . . . . 6.
6. Vertex distinctly margined; genae produced as small conical or padlike processes  
    or not swollen at all. . . . . **Paratrioza** p. 584.  
    Vertex not distinctly margined anteriorly, rounded down; genae spherically  
    swollen. . . . . **Kuwayama** p. 592.
7. Genae produced as long, slender, closely appressed processes; vertex not deeply  
    concave between eyes. . . . . **Neotriozeila** p. 593.  
    Genal processes short, divergent; vertex deeply concave between eyes  
    . . . . . **Metatrioza** p. 597.
8. Radius and media petiolate; basal vein (R+M+Cu) very long; antennal in-  
    sertions anterior. . . . . **Ceropsylla** p. 600.  
    Media and cubitus petiolate; basal vein not unusually long; antennal insertions  
    lateral. . . . . **Hemitrioza** p. 602.

Genus *Trioza*\* Förster

- 1848 *Trioza* Förster, Verh. natur. Ver. preuss. Rhein. 5:67.  
 1851 *Psylla* Fitch (pro parte), 4th Rept. N. Y. St. Mus. 64.  
 1861 *Trioza* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 336, 337-409.  
 1876 *Trioza* Scott, Trans. Ent. Soc. London 1876:551.  
 1879 *Trioza* Löw, Verh. zool.-bot. Ges. Wien 28:609.  
 1896 *Trioza* Edwards, Hemip.-Homop. Br. Is. 253-261.  
 1910 *Trioza* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1911 *Trioza* Crawford, Pom. Coll. Jour. Ent. 3:423.  
 1911 *Allotrioza* Crawford (pro parte), Pom. Coll. Jour. Ent. 3:423, 442.  
 1911 *Triozeila* Crawford (pro parte), Pom. Coll. Jour. Ent. 3:493.  
 1912 *Trioza* Oshanin, Kat. paläa. Hemip. 128 [designates type].  
 1913 *Trioza* Aulmann, Psy. Cat. 37.  
 1914 *Trioza* Crawford, U. S. Nat. Mus., Bull. 85:74.  
 1914 *Ceropsylla* Crawford (pro parte), U. S. Nat. Mus., Bull. 85:102.  
 1917 *Trioza* Van Duzee, Cat. Hemip. N. Am. 792.  
 1917 *Ceropsylla* Van Duzee (pro parte), Cat. Hemip. N. Am. 798.  
 1926 *Spanioza* Enderlein, Ent. Mitt. 15:400.  
 1926 *Colopelma* Enderlein, Ent. Mitt. 15:400.  
 1926 *Phyllopecta* Ferris, Can. Ent. 58:16.  
 1938 *Phyllopecta* Caldwell, Ohio Biol. Surv., Bull. 34:248.

Head usually narrower than thorax, sometimes as wide, somewhat deflexed. Vertex much broader than long, usually deeply impressed distally, more or less emarginate medially in front. Genae produced as processes of varying length and shape, more or less divergent, depressed

\* From *triozos*, Gr. adj.—with three branches.

from plane of vertex and usually deflexed more or less. Antennae slender, variable in length from about as long as width of head to  $2\frac{1}{2}$  times as long. Eyes hemispherical. Thorax usually strongly arched. Pronotum short, descending cephalad, often depressed below plane of head. Propleurites not equal, suture not extending to middle of pronotum. Prescutum usually about as long as broad, sometimes longer. Forewings membranous, hyaline, typically acutely angled apically, sometimes rounded; radius, media, and cubitus arising from basal vein ( $R + M + Cu$ ) at same point, no pterostigma. Metatibia often with basal spur or carina, one outer and either two or three inner apical spines. Metatarsus without spines. Metacoxa often developed anteriorly as flat plate or spur.

Logotype: *Trioza urticae* (Linnaeus).

In 1884 Riley (Proc. Am. Assoc. Adv. Sci. 1883, 32: 319) used the name *Phylloplecta tripunctata* with no characterization or indication, leaving it a *nomen nudum*. Subsequently (1885), he lists all of the species "actually described" (18 in all) from North America and makes no mention of *Phylloplecta*. In this paper he refers *Psylla tripunctata* Fitch to *Trioza*. Mally (1894), in a footnote, points out that Riley used the name *Phylloplecta* without any description and raises the question as to whether it was meant to be the same as *Trioza tripunctata* (Fitch) or some other species.

The next use of the name was by Zacher in 1913 (Ent. Mitt. 2: 148). In indicating omissions from Aulmann's catalogue, he lists "Phylloplecta für *Trioza tripunctata* Fitch, cf. Riley, 1883." This was not a proposal of the name *Phylloplecta* for *Trioza tripunctata* by Zacher but a reference to Riley's *nomen nudum*. Ferris (1926) considers this as the designation of a type for a new genus, *Phylloplecta* Zacher. It is my opinion, however, that this listing of a *nomen nudum* does not constitute the proposal of a new genus with *tripunctata* as the type. Ferris misspells the name and so actually establishes the genus *Phyllopecta* Ferris. Caldwell (1938a) resurrects *Phylloplecta* Riley, refusing to recognize it as a *nomen nudum*. He likewise credits Zacher with *Phyllopecta*, apparently following Ferris' reference.

The cephalically projecting spurs on the metacoxae of this species (*tripunctata*) have apparently been the chief basis on which the genus *Phylloplecta* has been maintained. The presence of these spines has been considered by a number of workers to be of more importance than I believe is valid. As Caldwell (1938a) recognizes, many species of *Triozinae* exhibit a pair of spurs or an apparent tendency toward such processes between the hind legs. *Trioza minuta*, *Trioza maura*, *Trioza rubra*, to mention a few, have short but distinctly developed processes in this position. In the genus *Paratrioza* these spurs are well developed in most of the species, especially in *P. arbolensis* and *P. cockerelli*. These spurs may even be found on members of other subfamilies, in the genus *Rhinopsylla* for example. I fail to agree, therefore, that the mere presence of such a spur is of generic importance and so consider *Phylloplecta* and *Phyllopecta* as synonyms of *Trioza*.

The genus *Megatrioza* was established by Crawford (1915) for a Philippine species. Subsequently (1919), he referred the North American species *Triozia diospyri* (Ashmead) to this genus where it seems to belong on the basis of his characterization and figures of the genus. *Megatrioza* seems to be a natural group of species, but I am somewhat doubtful of its being of generic rank. The characters given for the genus are all apparently extremely variable within the group with the exception of the number of inner apical spines and the presence of "a small or large spur at base" of hind tibia, the presence of a pair of spiniform processes projecting cephalad on the metacoxae, and the reduction in size of the hind wings. Since I have seen few specimens of *Megatrioza* other than *diospyri*, I am unwilling to abolish it, but I feel that it is probably worthy of no more than subgeneric rank.

Ferris (1926) considered *Megatrioza* a synonym of *Phylloplecta*, stating that *diospyri* and *tripunctata* are "actually congeneric, all of the characters given by Crawford for *Megatrioza* being equally well developed in both, if not even more strongly in *tripunctata*." This is not true, as *tripunctata* has only two inner spines at the apex of the tibia (a character hardly of generic significance, however), the anterior metacoxal spines while present are small while the caudal metacoxal spines are unusually small for the *Triozinae*. Large basal tibial spurs are present in *tripunctata*, but this character occurs in some species of most of the genera with which I am familiar. They are entirely lacking in *diospyri*. Furthermore, the head is quite different, as is the wing venation, the latter being as distinct in the two species as in any of the North American *Triozinae*. If these two species are congeneric, it must be within the genus *Triozia*, which contains other species more similar to *tripunctata* than *diospyri*.

Enderlein's genera *Spanioza* and *Colopelma* were based on characters which are too minor to be valid.

Crawford considered *Petalolyma* Scott a synonym of *Triozia*. There is nothing in Scott's description to distinguish the two, but his figure of the wing does not appear to be that of a species of *Triozia*.

### Key to the Species of *Triozia*

1. Hind tibiae with two inner apical spines.....2.
- Hind tibiae with three inner apical spines.....21.
2. ( 1) Forewings not maculate, hyaline or evenly infuscated (except radular areas) .3.
- Forewings distinctly maculate.....18.
3. ( 2) Genal processes longer than vertex.....pulla p. 552
- Genal processes not longer than vertex (usually distinctly shorter) .....4.
4. ( 3) Antennae at least twice as long as width of head.....5.
- Antennae less than twice as long as width of head (rarely over  $1\frac{3}{4}$  times as long) .....8.
5. ( 4) Antennae  $2\frac{1}{2}$  times as long as width of head; Rs very short, arcuate to costa; small species, 2.5 to 2.75 mm.....viridis p. 552.
- Antennae twice as long as width of head; Rs long, slightly sinuate or straight; large species, 3.25 to 4.5 mm.....6
6. ( 5) Prescutum longer than wide.....magnoliae p. 553.
- Prescutum wider than long.....7.

7. ( 6) Head almost as wide as thorax. . . . . *singularis* p. 554.  
 Head much narrower than thorax. . . . . *longicornis* p. 554.
8. ( 4) Genal processes not over  $\frac{1}{2}$  as long as vertex. . . . . 9.  
 Genal processes over  $\frac{1}{2}$  (usually  $\frac{3}{4}$ ) as long as vertex. . . . . 11.
9. ( 8) Genal processes strongly divergent, acute; wings short. . . . . 10.  
 Genal processes contiguous or very slightly divergent, blunt; wings long and slender. . . . . *alacris* p. 555.
10. ( 9) Rs more than  $\frac{1}{2}$  as long as entire forewing; green species. . . . . *stygmia* p. 556.  
 Rs less than  $\frac{1}{2}$  as long as entire forewing; brown species. . . . . *shepherdiae* p. 557.
11. ( 8) Marginal cells of forewing very small; female genital segment over  $\frac{1}{2}$  as long as rest of abdomen. . . . . 12.  
 Marginal cells of forewing typical size for *Trioza*; female genital segment less than  $\frac{1}{2}$  as long as rest of abdomen. . . . . 14.
12. (11) Genal processes  $\frac{3}{4}$  as long as vertex; forewings  $2\frac{1}{2}$  times as long as wide; female genital segment  $\frac{3}{4}$  to fully as long as rest of abdomen; male forceps acute apically. . . . . 13.  
 Genal processes slightly over  $\frac{1}{2}$  as long as vertex; forewings short (scarcely more than twice as long as wide); male forceps much enlarged apically. . . . . *stylifera* p. 557.
13. (12) Dorsal valve of female genital segment straight and acute apically. . . . . *occidentalis* p. 558.  
 Dorsal valve of female genital segment upturned and blunt apically. . . . . *rubicola* p. 559.
14. (11) Antennae  $1\frac{1}{2}$  times as long as width of head. . . . . 15.  
 Antennae at least  $1\frac{3}{4}$  times as long as width of head. . . . . 17.
15. (14) General color black; female genital segment straight and acute. *incerta* p. 564.  
 General color green to orange, head often black; female genital segment shorter, strongly curved ventrad. . . . . 16.
16. (15) Vertex strongly bulging anteriorly; caudal lobes of male proctiger short, only  $\frac{1}{2}$  as long as axial portion. . . . . *minuta* p. 562.  
 Vertex not strongly bulging; caudal lobes of male proctiger as long as axial portion. . . . . *maura* p. 560.
17. (14) Body unicolorous, red to almost black. . . . . *rubra* p. 565.  
 Body black with extensive yellow to red markings including longitudinal stripes on dorsum of thorax. . . . . *varians* p. 564.
18. ( 2) Dorsum of head and thorax pubescent (sparsely); maculation of forewings extensive, maculae brown with many small darker brown spots. . . . . *lobata* p. 566.  
 Dorsum of head and thorax not pubescent; maculation less extensive, maculae not spotted. . . . . 19.
19. (18) Marginal cells of forewing small, extremely short but wide; brown maculae along cubitus, media and apical portion of Rs, more or less continuous along margin. . . . . *tripunctata* p. 567.  
 Marginal cells normal; maculation otherwise. . . . . 20.
20. (19) Entire posterior margin of forewing brown; Rs long, sinuate. . . . . *minuta* var. *arizonae* p. 563.  
 Basal vein (R+M+Cu),  $R_1$  and posterior margin of clavus, brown; Rs short, arched to costa. . . . . *californica* p. 568.
21. ( 1) Antennae no longer than width of head. . . . . 22.  
 Antennae distinctly longer than width of head. . . . . 24.
22. (21) Small species (2.75 mm.), not pubescent, uniformly yellow in color. . . . . *phoradendri* p. 569.  
 Large species (4 to 4.5 mm.), sometimes pubescent. . . . . 23.
23. (22) Light colored species, vertex and thoracic dorsum more or less pubescent. . . . . *bakeri* p. 570.  
 Dark species, at least the vertex black, not pubescent. . . . . *breviantennata* p. 570.
24. (21) Vertex and thoracic dorsum with long conspicuous pubescence. . . . . 25.  
 Vertex and thoracic dorsum not conspicuously pubescent. . . . . 26.





*Trioza urticae*\* (Linn.)

(Figs. 163, 164, 165, 262)

- 1758 *Chermes urticae* Linnaeus, Syst. Nat. 10:454.  
 1761 *Chermes urticae* Linnaeus, Fauna Svec. 263.  
 1841 *Psylla urticae* Hartig, Germ. Zeitschr. Ent. 3:374.  
 1841 *Psylla eupoda* Hartig, Germ. Zeitschr. Ent. 3:374.  
 1848 *Trioza urticae* Förster, Verh. natur. Ver. preuss. Rhein. 5:82.  
 1848 *Trioza eupoda* Förster, *ibid.* 82.  
 1848 *Trioza protensa* Förster, *ibid.* 82.  
 1848 *Trioza forcipata* Förster, *ibid.* 84.  
 1848 *Trioza crassinervis* Förster, *ibid.* 83.  
 1861 *Trioza urticae* Flor, Rhynch. Liv. 2:505-508.  
 1861 *Trioza urticae* Flor, Bull. Soc. Imp. Nat. Moscou 34:383, 387, 392.  
 1872 *Trioza urticae* Meyer-Dür, Mitt. Schw. Ent. Ges. 3:386.  
 1872 *Trioza crassinervis* Meyer-Dür, *ibid.* 387.  
 1872 *Trioza eupoda* Meyer-Dür, *ibid.* 389.  
 1872 *Trioza protensa* Meyer-Dür, *ibid.* 389.  
 1872 *Trioza forcipata* Meyer-Dür, *ibid.* 389.  
 1872 *Trioza bicolor* Meyer-Dür, *ibid.* 389, 391.  
 1876 *Trioza urticae* Scott, Trans. Ent. Soc. London 1876:553.  
 1877 *Trioza urticae* Thomson, Opusc. Ent. 8:827.  
 1878 *Trioza urticae* Löw, Verh. zool.-bot. Ges. Wien 27:141.  
 1896 *Trioza urticae* Edwards, Hemip.-Homop. Br. Is. 254, 256.  
 1908 *Trioza urticae* Oshanin, Verz. palae. Hemip. 2:375.  
 1912 *Trioza urticae* Oshanin, Kat. palae. Hemip. 129.  
 1925 *Trioza urticae* Ferris, Can. Ent. 57:47 (nymph).  
 1930 *Trioza urticae* Klyver, Can. Ent. 62:169.

Length to tip of folded wings 3.5 to 3.75 mm.

**COLOR:** General color greenish yellow to light brown. Genal processes black or brown-tipped. Tip of legs, antennae, and margins of abdominal and thoracic sclerites more or less embrowned. Wings hyaline, clear to slightly yellowish.

**STRUCTURE:** Head small, narrower than thorax. Vertex depressed discally, roundly protruding anteriorly. Genal processes acute, divergent, extending anteriorly,  $\frac{2}{3}$  as long as vertex. Antennae nearly twice as long as width of head. Thorax strongly arched. Pronotum depressed below plane of vertex. Forewings rounded apically; Rs long, nearly straight, M evenly curved, marginal cells small. Legs long, slender. Hind tibia without basal armature, with one outer and three inner apical spines.

**GENITALIA:** Male proctiger small, broadly produced caudad. Forceps longer than proctiger; in lateral view narrow, enlarged apically then narrowed to subacute apices, latter hooked cephalad (see fig. 164). Female genital segment  $\frac{1}{2}$  to  $\frac{2}{3}$  as long as rest of abdomen, valves nearly equal in length, straight to acute apices.

This species, the type of the genus, does not occur in North America although a very closely related form (*T. albifrons*) is very abundant. It has been recorded from all of Europe including Scandinavia, Russia, Transcaucasia, and Siberia. The above description is from eight specimens from Europe and Reshadieh, Turkey. As the name indicates, its host plant is *Urtica*—nettle. Ferris (1925) figures the nymph.

\* Genitive of *Urtica*—the generic name of the host plant.



*Trioza pulla*\* Tuthill

(Figs. 153, 154, 297)

1939 *Trioza pulla* Tuthill, Ia. St. Coll. Jour. Sci. 13:184.

Length to tip of folded wings 3.5 mm.

COLOR: Head, thorax, femora, and apical half of antennae fuscous. Remainder of legs and antennae pale. Abdomen green. Wings milky. Females lighter, vertex and thoracic dorsum fusco-testaceous.

STRUCTURE: Head broad. Vertex quite flat for *Trioza*. Antennae long, almost twice as long as width of head. Genal processes slender, acute, slightly longer than head, projecting downward, straight, not touching at all. Genal processes, legs, and genitalia very pubescent. Thoracic dorsum not very strongly arched. Hind tibia with large serrate basal carina, two inner apical spines. Anterior portion of metacoxa weakly developed. Forewings large,  $2\frac{1}{2}$  times as long as wide, narrowly rounded apically; Rs long.

GENITALIA: Male genitalia small. Proctiger with long, blunt, caudal lobes. Forceps quite broad at base, sharply narrowed midway, then tapering to truncate apices with small anterior tooth. Female genital segment about  $\frac{1}{3}$  as long as remainder of abdomen; dorsal valve rounding down to acute black apex; ventral valve shorter.

Known only from the type series from Washington and Oregon.

HOLOTYPE, male, No. 55179 United States National Museum.

*Trioza viridis*† Crawford

(Figs. 166, 167, 264)

1910 *Trioza viridis* Crawford, Pom. Coll. Jour. Ent. 2:230, 350.1911 *Allotrioza viridis* Crawford, Pom. Coll. Jour. Ent. 3:444, 446.1913 *Trioza viridis* Aulmann, Psy. Cat. 57.1914 *Trioza viridis* Crawford, U. S. Nat. Mus., Bull. 85:95.1917 *Trioza viridis* Van Duzee, Cat. Hemip. N. Am. 797.1925 *Trioza viridis* Crawford, Proc. Haw. Ent. Soc. 6, 1:30.1926 *Spanioza viridis* Enderlein, Ent. Mitt. 15:400.

Length to tip of folded wings 2.5 to 2.75 mm.

COLOR: Greenish yellow, except apical  $\frac{2}{3}$  of antennae and tip of female genital segment, black.

STRUCTURE: Head large, not deflexed. Vertex long, with two longitudinal sulcate impressions. Genal processes large, blunt, extending forward, almost on same plane as vertex, slightly over  $\frac{1}{2}$  as long as vertex. Antennae slender, almost  $2\frac{1}{2}$  times as long as width of head. Thorax rather flat and broad. Pronotum long and flat, somewhat below plane of vertex. Forewings acute,  $2\frac{1}{2}$  times as long as wide; Rs very short, arched. Hind tibia with two inner apical spines.

GENITALIA: Male proctiger long, almost parallel-sided, slightly pro-

\* *pullus* -a -um, L. adj.—dark colored.

† *viridis* -e, L. adj.—green.

duced caudad. Forceps shorter than proctiger; in lateral view broad basally, slightly narrowed and flexed caudad in apical  $\frac{2}{3}$ ; in caudal view slender, almost straight to black, truncate apices. Female genital segment large, about as long as rest of abdomen; ventral valve straight to acute black apex; dorsal valve longer than ventral, basal portion swollen, distal portion acuminate and upcurved, black.

Six specimens from Monrovia and one from Claremont, California, are at hand. These are the only specimens reported besides the type series (3), one female from Los Angeles and one female taken on Mt. San Antonio, California. Type locality Claremont, California.

TYPE in Crawford Collection, Mountains near Claremont, California, Baker.

*Trioza magnoliae*\* (Ashmead)

(Figs. 168, 169)

1881 *Psylla magnoliae* Ashmead, Can. Ent. 13:224.

1885 *Trioza magnoliae* Riley, Proc. Biol. Soc. Wash. 2:70.

1911 *Allotrioza magnoliae* Crawford, Pom. Coll. Jour. Ent. 3:444, 445.

1913 *Psylla magnoliae* Aulmann, Psy. Cat. 19.

1914 *Trioza magnoliae* Crawford, U. S. Nat. Mus., Bull. 85:96.

1917 *Trioza magnoliae* Van Duzee, Cat. Hemip. N. Am. 797.

1919 *Trioza magnoliae* Barber, Proc. Ent. Soc. Wash. 21:59.

Length to tip of folded wings 3.5 to 4.5 mm.

COLOR: General color green to light brown with brown stripes on thoracic dorsum. Tips of antennae dark. Eyes reddish. Wings hyaline.

STRUCTURE: Head large, as broad as thorax, scarcely deflexed. Vertex large, flat except for discal impressions, medial suture prominent. Genal processes short, blunt, divergent, about  $\frac{1}{2}$  as long as vertex. Antennae twice as long as width of head. Vertex and dorsum of thorax often with sparse short pubescence, most apparent near eyes. Thorax somewhat arched, long. Prothorax not depressed below plane of vertex, caudal margin upcurved, carinate. Prescutum distinctly longer than wide, anterior angle very sharp and abrupt. Forewings large, straight, sharply angulate, almost 3 times as long as wide. Hind tibia with large, serrate, basal carina, two inner apical spines.

GENITALIA: Male proctiger small, arcuate posteriorly from near apex. Forceps slightly longer than proctiger; in lateral view broad, somewhat pyriform, anterior margin strongly curved caudad, apices blunt, black, in line with posterior margin; in caudal view almost straight, slightly arcuate, apices touching. Female genital segment large,  $\frac{2}{3}$  as long as rest of abdomen, valves almost equal in length, acute.

Ashmead described this gall-forming species from *Magnolia glauca*, a synonym of *M. virginiana* L., the "laurel magnolia" or "sweet bay."

Specimens are at hand collected by E. A. Schwarz on *Persea carolinensis*, a synonym of *P. borbonia* (L.), "red bay," a member of the laurel family. Three specimens from Orlando, Florida, bear the label *Tamala*

\* Genitive of *Magnolia*—a genus of plants, presumed to be the host.

*borbonia*. I am unfamiliar with these trees, but it would seem that there has been some error in the determination of the host plant (see Barber, 1919).

Specimens are before me from several localities in Florida and from Mobile, Alabama. It is also recorded from southern Georgia.

Ashmead gives a brief account of the biology, including a description of the galls and nymphs. He remarks that the nymphs do not have the fringe of hairs on the body which most *Trioza* do have; cast skins accompanying some of the specimens at hand do bear such setae although they are quite short.

TYPE, female, No. 14819 United States National Museum, is a very poor, teneral specimen.

Type examined.

*Trioza singularis*\* n. sp.

(Figs. 155, 155a, 298)

Length to tip of folded wings 3.5 mm.

COLOR: General color of body black. Tibiae, abdominal sternites, antennae (except tips and segments I and II) white.

STRUCTURE: Head large, almost as broad as thorax. Vertex strongly bulging and overhanging anteriorly each side of median line, discal impressions large. Genal processes blunt, divergent from base,  $\frac{2}{3}$  as long as vertex. Antennae about twice as long as width of head. Thorax strongly arched, coarsely punctate. Pronotum much depressed below plane of vertex. Forewings sharply angulate, almost 3 times as long as wide, venation typical. Hind tibia with 2 inner apical spines. Anterior portion of metacoxa broadly produced, truncate.

GENITALIA: Male proctiger very short, produced on each side into long blunt caudal lobe, no anal epiphysis. Forceps longer than proctiger; in lateral view broad basally, constricted midway, slightly curving cephalad to acute apices; in caudal view broad and divergent basally, at about  $\frac{1}{2}$  their length suddenly narrowed and directed dorsad to acute apices, with a sharp lateral hook near apex, appearing almost T-shaped.

Described from a unique male collected in Cheboygan County, Michigan, by H. B. Hungerford, July 23, 1931. Type in Snow Collection, University of Kansas, Lawrence, Kansas.

*Trioza longicornis*† Crawford

1910 *Trioza longicornis* Crawford, Pom. Coll. Jour. Ent. 2:231, 359.

1911 *Trioza longicornis* Crawford, Pom. Coll. Jour. Ent. 3:425, 427.

1912 *Trioza dubia* Patch, Me. Agr. Exp. Sta., Bull. 202:226.

1912 *Trioza forcipula* Patch, Me. Agr. Exp. Sta., Bull. 202:227.

1913 *Trioza longicornis* Aulmann, Psy. Cat. 48.

1914 *Trioza longicornis* Crawford, U. S. Nat. Mus., Bull. 85:92.

1917 *Trioza longicornis* Van Duzee, Cat. Hemip. N. Am. 797.

1926 *Spanioza forcipula*, Enderlein, Ent. Mitt. 15:400.

1928 *Trioza forcipula* Leonard, Ins. N. Y. 183.

\* *singularis* -e, L. adj.—remarkable, unique.

† From *longus* -a -um, L. adj.—long + *cornu* -us, L. n. noun—horn.

Length to tip of folded wings 3.75 mm.

COLOR: Described as greenish yellow, now faded to a uniform tan.

STRUCTURE: Head narrower than thorax. Vertex plane, edges raised, platelike, discal impressions and medial suture prominent. Genal processes subacute, about as long as vertex. Antennae twice as long as width of head. Thorax strongly arched. Pronotum depressed below plane of vertex. Forewings hyaline,  $2\frac{1}{3}$  times as long as wide, apex scarcely angulate. Hind tibia with two inner apical spines.

GENITALIA: Female genital segment with ventral valve as long as preceding sternite, straight; "dorsal valve longer than ventral"—Crawford.

The dorsal valve of the type and only specimen is apparently broken off. I have examined the TYPE (No. 18089 United States National Museum).

Crawford (1914) refers *Trioza dubia* to *minuta*, but from Miss Patch's picture of the female genital segment, I think it more probable that it belongs here. It is quite possible that *Trioza incerta* is synonymous with *dubia* or *forcipula* or both, but as no specimens of these species have been available I am unwilling to further confuse the literature by resurrecting these names.

### *Trioza alacris*\* Flor

(Figs. 170, 171)

- 1861 *Trioza alacris* Flor, Bull. Soc. Imp. Nat. Moscou 34:335, 380, 386, 398-400.  
 1879 *Trioza lauri* Targioni, Res. Soc. Ent. Ital. 19-20.  
 1908 *Trioza alacris* Oshanin, Verz. palae. Hemip. 2:372.  
 1912 *Trioza alacris* Oshanin, Kat. palae. Hemip. 129.  
 1912 *Trioza alacris* Crawford, Calif. Comm. Hort. Mon., Bull. 1:86-87.  
 1913 *Trioza alacris* Aulmann, Psy. Cat. 38.  
 1914 *Trioza alacris* Crawford, U. S. Nat. Mus., Bull. 85:94.  
 1917 *Trioza alacris* Weiss, Ent. News 28:96.  
 1917 *Trioza alacris* Weiss, Can. Ent. 49:73-75.  
 1917 *Trioza alacris* Essig, Jour. Ec. Ent. 10:439-444.  
 1917 *Trioza alacris* Van Duzee, Cat. Hemip. N. Am. 797.  
 1918 *Trioza alacris* Weiss and Dickerson, Psyche 25:59-63.  
 1926 *Spanioza alacris* Enderlein, Ent. Mitt. 15:400.  
 1932 *Trioza alacris* Klyver, Ent. News 43:37.  
 1935 *Trioza alacris* Haupt, Tierw. Mitt. 4, 3:251.

Length to tip of folded wings 4 mm.

COLOR: General color of specimen at hand yellow-white, brown markings on abdomen and dorsum of thorax, latter forming longitudinal stripes. Lighter specimens "greenish yellow to light brown." Tip of antennae black. Wings hyaline.

STRUCTURE: Head large, almost as broad as thorax. Vertex with two very prominent discal foveae. Genal processes projecting forward, blunt,  $\frac{1}{2}$  as long as vertex. Antennae about  $1\frac{1}{3}$  times as long as width of head. Thorax rather flat for genus. Pronotum not at all depressed below vertex. Forewings long and slender, acute, almost 3 times as long as broad;

\* *alacer* -*cris* -*e*, L. adj.—quick, active.

Rs short. Hind tibia with two inner apical spines. Metacoxa with short, broad, anterior process.

GENITALIA: "Male anal valve (proctiger) a little longer than forceps, hind margin arcuate, with long pubescence; forceps rather stout, sides almost parallel (from side), terminating in a subacute, black point at apex."—Crawford.

Female genital segment about  $\frac{1}{2}$  as long as rest of abdomen ("nearly as long as"—Crawford); valves subequal in length, dorsal valve slightly excavate.

This species apparently occurs in North America only on bay trees (*Laurus nobilis*). It was recorded from California in 1912 by Crawford. Essig subsequently (1917) discusses it in some detail, gives life history notes and figures. Weiss and Dickerson record the occurrence of this insect in New Jersey, give notes on its life history there and describe the immature stages.

Outside of North America it is recorded from France, Spain, Portugal, Italy, Dalmatia, Hungary, and Germany.

*Trioza stygma*\* Tuthill

(Figs. 156, 157, 299)

1939 *Trioza stugma* Tuthill, Ia. St. Coll. Jour. Sci. 13:183.

Length to tip of folded wings 2.5 mm.

COLOR: General color green. Eyes, antennae, distal portions of leg segments, etc., light fulvous. Forewings slightly infuscated.

STRUCTURE: Head almost as wide as thorax. Vertex with two prominent foveae, very strongly protruded in front on each side of medial sulcus, overhanging the short genal processes, latter  $\frac{1}{2}$  as long as vertex. Antennae  $1\frac{1}{4}$  times as long as width of head. Thorax not strongly arched. Pronotum short, depressed below plane of vertex. Forewings rounded at apex,  $2\frac{1}{2}$  times as long as wide; venation typical. Hind tibia with two inner apical spines and basal carina.

GENITALIA: Male genitalia small. Proctiger short, somewhat produced caudally. Forceps very short and broad in lateral view, apices rounded and bearing a large, medially projecting, black-pointed tooth. Female genital segment short, valves subequal in length, dorsal straight, ventral concave dorsally.

Known only from the type series from California. Host plant unknown.

The name was originally spelled *stugma*, an error of transliteration. HOLOTYPE, male, No. 55180 United States National Museum.

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\* From *stygmus* Gr. adj.—that produces grief.



*Trioza shepherdiae*\* Tuthill

(Figs. 158, 159, 300)

1938 *Trioza shepherdiae* Tuthill, Ent. News 49:243.1939 *Phyllopecta multidubiata breviradia* Caldwell, Can. Ent. 71:211.1939 *Phyllopecta multidubiata breviradia* Strickland, Can. Ent. 71:214.1940 *Phyllopecta minuta breviradia* Caldwell, Ohio Jour. Sci. 40:50.

Length to tip of folded wings 2.5 mm.

COLOR: General color of head, thoracic dorsum and legs light testaceous to fulvous. Vertex light except discal impressions. Genal processes, eyes, distal half of antennae dark. Prescutum with a pair of brown stripes on cephalic half. Scutum with two inverted, V-shaped, brown marks. Wing membranes slightly fumate; veins brown. Abdomen brown to black.

STRUCTURE: Head and thoracic dorsum coarsely granular. Head of medium size, narrower than thorax. Vertex decidedly emarginate in front, with very prominent discal impressions, postero-lateral angles, which bear ocelli, raised. Genal processes short, about  $\frac{1}{2}$  as long as vertex, conical, almost parallel to plane of vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Pronotum depressed below plane of vertex. Prescutum strongly arched. Forewings  $2\frac{1}{2}$  times as long as wide, membrane rather thick, slightly rugose; venation typical. Hind wings more rugose than forewings. Legs of medium length. Hind tibia with serrate basal carina, two inner apical spines. Anterior portion of metacoxa bluntly produced.

GENITALIA: Male genital segment small. Proctiger as long as forceps, almost right-triangular in lateral view, posterior lobe of medium length. Forceps slender, irregularly narrowed to sharp apices, with medium pubescence. Female genital segment short, dorsal valve decidedly longer than ventral, terminating in a heavy, black, upcurved hook, usually exceeded by partially extended ovipositor sheath.

The type series from Lake City, Colorado, and additional specimens from Wolf Creek Pass, Colorado, are at hand. Examination of paratypes of Caldwell's *Trioza multidubiata breviradia* prove it to be synonymous with *shepherdiae*. Host, *Shepherdia canadensis* (L.) Nutt.

TYPE, female, in author's collection.

*Trioza stylifera*† Patch

(Fig. 172)

1912 *Trioza stylifera* Patch, Me. Agr. Exp. Sta., Bull. 202:229.1914 *Trioza stylifera* Crawford, U. S. Nat. Mus., Bull. 85:93.1917 *Trioza stylifera* Van Duzee, Cat. Hemip. N. Am. 797.

Length to tip of folded wings 2.75 mm.

COLOR: General color dark brown. Margins of vertex, median line on scutum, legs, and venter, lighter. Forewings somewhat yellowish.

STRUCTURE: Head narrower than thorax. Vertex broad, margins

\* Genitive of *Shepherdia*—the generic name of the host.

† From *stylus* -i, L. m. noun—style + *fer* (from *fero*) L.—bearing.



raised. Genal processes slightly over  $\frac{1}{2}$  as long as vertex, somewhat divergent, blunt. "Antennae about one and one-half times as long as width of head" (Crawford). Pronotum strongly descending cephalad, depressed below plane of vertex. Dorsum of thorax punctate. Forewings short, slightly over twice as long as wide, very slightly and broadly angulate, costal margin strongly arched; Rs slightly sinuate, short, medial cell somewhat smaller than cubital. Hind tibia with two inner apical spines, serrate basal carina.

**GENITALIA:** Male genital segment large. Proctiger short, bearing on each side a swollen bladder-like caudal lobe which extends dorsad, equalling axial portion. Forceps heavy; in lateral view large basally, a blunt tooth on caudal edge, narrowed and sharply curved cephalad at  $\frac{1}{3}$  their length, apical third much enlarged, apices roundly truncate, anterior margin of enlarged portion straight to apex, there produced as a small tooth; in caudal view stout, broad basally, produced into a blunt tooth both mesad and laterad, narrowed somewhat, swollen apically, apices truncate and flatly produced mesad. "The female cauda is relatively long and acutely pointed. The upper plate extends a bit beyond the ovipositor and is slender at tip." (Patch).

Described from one rather poor male specimen in the collection of the University of Minnesota collected at Herchmer, Manitoba, August 1, 1937, by D. G. Denning. The peculiar male forceps make the determination of this male almost certain, although I have seen none of Patch's specimens. Her type series was from Brockville, Ontario.

*Trioza occidentalis*\* Tuthill

(Figs. 160, 173, 173a, 301)

1939 *Trioza occidentalis* Tuthill, Ia. St. Coll. Jour. Sci. 13:184.

Length to tip of folded wings 4 mm.

**COLOR:** Males dark on head and thoracic dorsum. Females uniformly golden brown (?).

**STRUCTURE:** Head narrower than thorax. Vertex plane, raised. Genal processes large, thick, conical,  $\frac{2}{3}$  as long as vertex. Antennae  $1\frac{3}{4}$  times as long as width of head. Thorax very strongly arched. Pronotum moderately long, strongly descending anteriorly, not depressed below plane of vertex. Prescutum very abrupt anteriorly. Forewings broad, rounded,  $2\frac{1}{2}$  times as long as wide; Rs slightly sinuate; marginal cells small, equal. Hind tibia with small serrate basal carina, two inner apical spines.

**GENITALIA:** Male genitalia of medium size. Proctiger swollen in appearance, produced caudad as two large lateral lobes as figured; in dorsal view lobes broad, nearly contiguous basally. Forceps shorter than proctiger; in lateral view broad basally, narrowed in apical half, evenly curved cephalad, apices acute; in caudal view slightly arched, broad

\* *occidentalis* -e, L. adj.—western.

basally, suddenly narrowed on medial margin about  $\frac{1}{2}$  distance from base. Female genital segment nearly as long as rest of abdomen; dorsal valve straight to acute tip; ventral valve almost as long as dorsal, straight, or ventral margin somewhat sinuate, apex acute.

A series of nine males and seven females is at hand from Puyallup, Washington, collected July 10, 1934, by W. W. Baker. These are the only specimens known besides the two females from which the species was originally described, one from Marin Co., California, the other Kaslo Creek, British Columbia. With these additional specimens for study it is evident that the resemblance of this species to *T. tripunctata* is more than superficial. The metacoxae are produced anteriorly but not to as marked an extent as in the latter species. As these specimens were taken on *Rubus parviflorus* and many of them are teneral, it appears that the host plants of the two forms are very close as *tripunctata* develops on other species of *Rubus*. One of the males from this series is designated as ALLOTYPE and is in the United States National Museum.

HOLOTYPE, female, No. 55181 United States National Museum, Marin County, California.

*Trioza rubicola*\* n. sp.

(Figs. 174, 175, 175a)

Length to tip of folded wings 3.5 mm.

COLOR: Undeterminable as specimens have been preserved in alcohol. Males quite dark on dorsum of head and thorax. Females unicolorous.

STRUCTURE: Head narrower than thorax. Posterior and lateral margins of vertex carinate. Genal processes conical, stout, not divergent,  $\frac{2}{3}$  as long as vertex. Antennae slightly over  $1\frac{3}{4}$  times as long as width of head. Thorax strongly arched. Pronotum broad laterally, narrower medially, nearly vertical medially, not depressed below plane of vertex. Anterior margin of prescutum vertical. Forewings membranous, slightly rugose, broad, almost  $2\frac{1}{2}$  times as long as wide; costa strongly curved, Rs sinuate, marginal cells small, about equal. Hind tibia with serrate basal carina, two inner apical spines.

GENITALIA: Male genitalia of medium size. Proctiger very similar to *occidentalis*. Forceps in lateral view stout basally, narrowed and sharply bent cephalad near base, nearly straight to near apices, apices tapered to acute tips, hooked cephalad; in caudal view nearly straight, lateral margins straight, medial margins sharply excavate near base. Female genital segment as long as rest of abdomen; dorsal valve straight, apex flattened, rounded and upturned; ventral valve slightly sinuate ventrally, straight, acute, shorter than dorsal.

Described from a series of eleven males and eight females collected at Tacoma, Washington, July 10, 1940, W. W. Baker, on *Rubus leucodermis*, which is apparently the host plant as many of the specimens are

\* From *Rubus*—generic name of host plant + *cola*, L.—inhabitant.

quite teneral. This species may be distinguished from *T. occidentalis*, which it resembles very closely, by its smaller size, smaller head, more deeply impressed vertex, and the genitalia. The tip of the dorsal valve of the female genital segment serves to distinguish the two forms very readily, the less strongly curved forceps of the male will serve to separate the specimens of that sex.

HOLOTYPE, female, No. 55177 United States National Museum. Holotype, allotype, and paratypes in United States National Museum, paratypes in author's collection.

*Trioza maura*\* Förster

(Figs. 176, 177)

- 1848 *Trioza maura* Förster, Verh. natur. Ver. preuss. Rhein. 5:94.
- 1872 *Trioza maura* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:387.
- 1872 *Trioza helvetina* Meyer-Dür, Mitt. Sch. Ent. Ges. 3:388, 391.
- 1908 *Trioza maura* Oshanin, Verz. palae. Hemip. 2:376.
- 1910 *Trioza nigrifrons* Crawford, Pom. Coll. Jour. Ent. 2:230.
- 1910 *Trioza fulvida* Crawford, Pom. Coll. Jour. Ent. 2:231, 358.
- 1910 *Trioza fulvida similis* Crawford, Pom. Coll. Jour. Ent. 2:231, 359.
- 1910 *Trioza aurantiaca* Crawford, Pom. Coll. Jour. Ent. 2:231, 360.
- 1911 *Trioza aurantiaca* Crawford, Pom. Coll. Jour. Ent. 3:628.
- 1912 *Trioza maura* Patch, Me. Agr. Exp. Sta., Bull. 202:228.
- 1912 *Trioza maura* Oshanin, Kat. palae. Hemip. 129.
- 1913 *Trioza maura* Aulmann, Psy. Cat. 49.
- 1913 *Trioza aurantiaca* Aulmann, Psy. Cat. 39.
- 1913 *Trioza fulvida* Aulmann, Psy. Cat. 46.
- 1913 *Trioza nigrifrons* Aulmann, Psy. Cat. 50.
- 1914 *Trioza maura* Crawford, U. S. Nat. Mus., Bull. 85:89.
- 1914 *Trioza saliciperda* Crawford, U. S. Nat. Mus., Bull. 85:89.
- 1917 *Trioza maura* Van Duzee, Cat. Hemip. N. Am. 795.
- 1925 *Trioza maura* Crawford, Proc. Haw. Ent. Soc. 6, 1:30.
- 1928 *Trioza maura* Leonard, Ins. N. Y. 183.
- 1932 *Trioza maura* Klyver, Pan-Pac. Ent. 8:14.
- 1932 *Trioza maura* Klyver, Ent. News 43:37.
- 1935 *Trioza maura* Haupt, Tierw. Mittel. 4, 3:247.
- 1938 *Trioza maura* Strickland, Can. Ent. 70:204.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: Color extremely variable, most typical coloration reddish brown, but often darker. Head testaceous to black. Genal processes vary from almost white to black. Antennae white basally, dark distad. Abdomen usually darker than thorax but often white ventrad, entire abdomen frequently green. Forewings sometimes fumose.

STRUCTURE: Head narrower than thorax, somewhat deflexed. Vertex somewhat platelike, discal impressions from very shallow to prominent, anterior margin abrupt, scarcely bulging. Genal processes broad basally, acute, divergent, about  $\frac{2}{3}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Pronotum depressed below plane of vertex. Forewings variable in length, from  $2\frac{1}{2}$  to almost 3 times as long as wide, roundly angulate. Hind tibia with basal spur, two inner apical spines. Anterior portion of metacoxae bluntly produced.

GENITALIA: Male genitalia small. Proctiger short, produced into two

\* From *mauros*, Gr. adj.—dark.

long lobes, as long as or longer than vertical axis of proctiger, blunt. Forceps in lateral view slender, curved cephalad distally, apices acute; in caudal view swollen basally, distal half very slender, arched apices touching. Female genital segment typically shorter than preceding abdominal sternite; ventral valve somewhat upcurved, with acute black tip; dorsal valve longer, curved ventrad, black at apex, acute.

This, one of the few holarctic species of psyllids, was described from Europe. As can be judged from the foregoing description, most of the characters are quite variable, as one would expect in such an abundant and widespread species. Like the three following species, it lives upon *Salix* spp.

All four of these *Salix*-inhabiting species are very closely related and somewhat difficult to distinguish one from another. *Trioza minuta* is very much like *maura*; in fact they seem to intergrade, but until their identicalness is established by biological evidence I am unwilling to abolish *minuta*. The female genitalia are almost indistinguishable. In typical specimens of *minuta* the anterior margin of the vertex is swollen and the genal processes are shorter than in *maura*. The male genitalia of typical specimens of the two are also sufficiently different to be readily separated. The color and markings of *varians* and *incerta* make them quite distinct from the other two species. In addition the male genitalia of *varians* are easily distinguished; the female genital segment, however, is much like *maura* in structure; the larger size and more rounded wings (almost as round as a *Psylla* wing) are quite distinct. The male genitalia of *incerta* are very similar to *maura*, but the female genital segment is distinctive; also the genal processes are more slender and placed farther back under the head.

Many of these distinguishing characters are largely differences in degree and are therefore difficult to describe and even to figure. If typical specimens of the different species are at hand, they can be quite readily separated. It is possible that these species hybridize with one another, thus causing much of the difficulty of separating them. It would not be strange if they did hybridize, as they occur on the same host plants and in enormous numbers. The chief difficulty in explaining some of the variations that occur as being a result of hybridization is that several short distinct series of what appear to be intermediates are at hand.

While collecting on willow near Creede, Colorado, I noted two forms of psyllids that I thought to be distinct, one red with a green abdomen occurring in enormous numbers on *Salix longifolia*, another yellowish, abundant on a broad-leaved, yellow-stemmed willow. I can, however, find no significant structural differences between the two forms; both are apparently *maura*. Patch, noting the same color variations, concluded that the lighter forms were teneral, but this is not the case. Much the same sort of variation has been noted by Caldwell in *minuta*.

Specimens of *maura* are at hand from the following states and provinces: California, Oregon, Washington, British Columbia, Alaska, Mon-

tana, Idaho, Utah, Nevada, Wyoming, Colorado, New Mexico, and Minnesota. It is also recorded from Alberta, Illinois, and New York.

*Trioza minuta*\* Crawford

(Figs. 178, 179)

- 1895 *Trioza salicis* Mally, Proc. Ia. Acad. Sci. (1894) 2:161.  
 [non] *Trioza salicis* Löw, Verh. zool.-bot. Ges. Wien 32:249. 1883.  
 1910 *Trioza salicis* Crawford, Pom. Coll. Jour. Ent. 2:232.  
 1910 *Trioza nigra* Crawford, Pom. Coll. Jour. Ent. 2:232, 358.  
 [non] *Trioza nigra* Kuw., Trans. Sap. Nat. Hist. Soc. 3:57. 1910.  
 1910 *Trioza minuta* Crawford, Pom. Coll. Jour. Ent. 2:232.  
 1910 *Trioza assimilis* Crawford, Pom. Coll. Jour. Ent. 2:233.  
 [non] *Trioza assimilis* Flor, Bull. Soc. Imp. Nat. Moscou 34:480. 1861.  
 1911 *Trioza minuta* Crawford, Pom. Coll. Jour. Ent. 3:425, 427, 432.  
 1911 *Trioza minuta similis* Crawford, Pom. Coll. Jour. Ent. 3:425, 427, 432.  
 1911 *Trioza assimilis* Crawford, Pom. Coll. Jour. Ent. 3:426, 429, 438.  
 1911 *Trioza nigra* Crawford, Pom. Coll. Jour. Ent. 3:427, 428.  
 1911 *Trioza salicis* Crawford, Pom. Coll. Jour. Ent. 3:426, 428, 432.  
 1911 *Trioza flori* Crawford, Pom. Coll. Jour. Ent. 3:503 (n. n. for *assimilis*).  
 1911 *Trioza nigrilla* Crawford, Pom. Coll. Jour. Ent. 3:503 (n. n. for *nigra*).  
 1912 *Trioza louisianae* Aulmann, Ent. Rund. 22 (n. n. for *nigra*).  
 1912 *Trioza pomonae* Aulmann, Ent. Rund. 22 (n. n. for *assimilis*).  
 1913 *Trioza louisianae* Aulmann, Psy. Cat. 48.  
 1913 *Trioza minuta* Aulmann, Psy. Cat. 49.  
 1913 *Trioza pomonae* Aulmann, Psy. Cat. 51.  
 1913 *Trioza salicis* Aulmann, Psy. Cat. 53.  
 1914 *Trioza salicis* Crawford, U. S. Nat. Mus., Bull. 85:91.  
 1917 *Trioza nigrilla* Van Duzee, Cat. Hemip. N. Am. 796.  
 1918 *Trioza salicis* McAtee, Ent. News 29:223.  
 1922 *Trioza nigrilla* Osborn, N. Y. St. Coll. For., Tech. Pub. 16:53.  
 1932 *Trioza salicis* Klyver, Ent. News 43:37.  
 1938 *Phyllopecta salicis* Caldwell, Ohio Biol. Surv., Bull. 34:250.  
 1939 *Phyllopecta multidubiate* Caldwell, Can. Ent. 71:211.  
 1939 *Phyllopecta multidubiate* Strickland, Can. Ent. 71:214.  
 1940 *Phyllopecta minuta* Caldwell, Ohio Jour. Sci. 40:50.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: Head usually black, or orange with some black markings. Genal processes sometimes white. Thorax orange, often with black markings. Abdomen typically green but frequently dark orange brown. Females lighter colored than males.

STRUCTURE: Head small, narrower than thorax. Vertex with discal impressions shallow, strongly bulging in front, overhanging median ocellus. Genal processes short, acute, divergent from base,  $\frac{3}{5}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched, pronotum depressed below plane of vertex. Forewings slender, angulate, almost 3 times as long as wide. Hind tibia with two inner apical spines, serrate basal carina. Metacoxa somewhat produced anteriorly.

GENITALIA: Male proctiger shorter than forceps, caudal lobes only  $\frac{1}{2}$  as long as axial portion. Forceps in lateral view slender, tapering from base to acute apices, apical third slightly flexed cephalad; in caudal view broad basally, slightly arched to acute apices. Female genital segment

\* *minutus* -a -um, L. adj.—small.



short; ventral valve upcurved, scarcely sharp at apex; dorsal valve strongly downcurved, longer than ventral, blunt.

This willow-inhabiting form was described by Mally in 1895 from specimens taken at Ames, Iowa, and named *Trioza salicis*. This name is preoccupied, however, by Löw's use of the name in 1882. Crawford in 1910 proposed three new names, *nigra*, *assimilis*, and *minuta*, for variants of the same species. In 1911 he changed the name *nigra* to *nigrilla* and *assimilis* to *flori* as these names were both preoccupied; subsequently (1914) he suppressed all of these names as synonyms of *Trioza salicis* Mally. As *salicis* is preoccupied, this leaves *minuta* as the oldest available name which has been applied to the species and therefore the name by which it must be designated.

Caldwell in 1938 referred the species to the genus *Phylloplecta* and erroneously resurrected the homonym *salicis*; this error was corrected in 1939, but he added another name *multidubiata*, to the already long list of synonyms which this species carries. Subsequently (1940), he correctly attributed the name *minuta* to the species.

Specimens are at hand from the following localities: Iowa, Illinois, Maryland, Louisiana, Oklahoma, Colorado, Arizona, California, Utah, Oregon, Washington, Idaho, and Montana. Caldwell records it from Ohio, gives the life history, and describes the immature stages. It is also recorded from New York and doubtlessly occurs over most of North America.

The type of *minuta* is assumed to be in the Crawford collection. The type of *T. salicis* Mally, female, Ames, Iowa, September 8, 1894, is in the Iowa State College Collection at Ames, Iowa.

The types of Crawford's various synonymic species are also assumed to be in his collection if they were ever selected.

*Trioza minuta* var. *arizonae*\* Aulmann

(Fig. 263)

- 1910 *Trioza marginata* Crawford, Pom. Coll. Jour. Ent. 2:232, 356.  
 [non] *Trioza marginata* Löw, Verh. zool.-bot. Ges. Wien 32:242, 1882.  
 1911 *Trioza marginata* Crawford, Pom. Coll. Jour. Ent. 3:424, 427.  
 1912 *Trioza marginata* Patch, Me. Agr. Exp. Sta., Bull. 202:228.  
 1912 *Trioza arizonae* Aulmann, Ent. Rund. Heft 22 [fide Aulmann, 1913].  
 1913 *Trioza arizonae* Aulmann, Psy. Cat. 39.  
 1914 *Trioza arizonae* Crawford, U. S. Nat. Mus., Bull. 85:88.  
 1917 *Trioza arizonae* Van Duzee, Cat. Hemip. N. Am. 795.

The brown posterior margin of the forewing is the character separating this variety from the typical form. This band, while quite distinctive, is hardly of specific value. Specimens are at hand from Arizona and from Oklahoma.

TYPE, female, No. 18087 United States National Museum, has all the wings broken off.

Type examined.

\* Genitive of Arizona.



*Trioza varians*\* Crawford

(Figs. 180, 181, 265)

- 1910 *Trioza varians* Crawford, Pom. Coll. Jour. Ent. 2:231, 361.  
 1911 *Trioza varians* Crawford, Pom. Coll. Jour. Ent. 3:425, 427.  
 1913 *Trioza varians* Aulmann, Psy. Cat. 57.  
 1917 *Trioza varians* Van Duzee, Cat. Hemip. N. Am. 796.  
 1938 *Trioza varians* Strickland, Can. Ent. 70:204.  
 1939 *Trioza varians* Strickland, Can. Ent. 71:214.

Length to tip of folded wings 4 to 4.25 mm.

COLOR: General color black. Tibiae, first tarsal segment, segment III of antennae, broad subapical band on dorsal valve of female genital segment, yellow. Vertex and dorsum of thorax with extensive testaceous markings. Vertex testaceous on margins and usually along median sulcus. Pronotum, posterior margin and mid-line of prescutum, longitudinal stripes on mesoscutum, scutellum, testaceous. Veins of forewings black.

STRUCTURE: Head narrow. Vertex raised, platelike, discal impressions prominent. Eyes appearing slightly stalked. Genal processes long, slender, acute, somewhat divergent,  $\frac{4}{5}$  as long as vertex. Antennae  $1\frac{3}{4}$  times as long as width of head. Thorax strongly arched. Pronotum entirely depressed below plane of vertex. Forewings about  $2\frac{1}{2}$  times as long as wide, very large, almost twice as long as body, apices rounded; Rs long and sinuate. Hind tibia with two inner apical spines, prominent, serrate, basal carina. Metacoxa moderately produced anteriorly.

GENITALIA: Male proctiger shorter than forceps, caudal lobes large, almost as long as vertical portion. Forceps in lateral view long, slender, sinuate, evenly tapering to rounded apices; in caudal view very broad basally, constricted and incurved midway, thence straight to apices. Female genital segment short; ventral valve straight, apex produced as a large tooth; dorsal valve twice as long as ventral, terminating as a blunt tooth.

Numerous specimens of this beautiful species are at hand from Colorado where it seems to be limited in distribution to altitudes of about 11,000 feet or more. In addition to these specimens, I have one from California and one from Ungava Bay, H. B. T. It is also recorded from Utah and Alberta.

TYPE, female, Colorado, C. F. Baker, No. 18088 United States National Museum.

Type examined.

*Trioza incerta*† n. sp.

(Figs. 161, 162, 302)

Length to tip of folded wings 3.25 to 3.5 mm.

COLOR: Color very much like *variens*. General color black. Mark-

\* Part. adj. of *vario*, L. v.—varied.

† *incertus* -a -um, L. adj.—unsettled.

ings orange red, almost identical pattern as *varians*. Females generally lighter. Male forceps apparently always white.

STRUCTURE: Head narrower than thorax, deflexed. Vertex with margins raised, platelike, discal impressions shallow. Genal processes about  $\frac{2}{3}$  as long as vertex, straight, divergent, acute. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Pronotum depressed below plane of vertex. Forewings about  $2\frac{1}{2}$  times as long as wide. Hind tibia with two inner apical spines, serrate carina basally. Metacoxa somewhat produced anteriorly.

GENITALIA: Male proctiger short, caudal lobes as long as vertical portion. Forceps longer than proctiger; in lateral view slender, evenly narrowed from base to acute apices, very strongly curved cephalad; in caudal view very large basally, constricted, then straight to apices. Female genital segment as long as rest of abdomen; ventral valve swollen basally, slender apical portion  $\frac{3}{4}$  as long as base; dorsal valve longer than ventral, somewhat attenuate apically, blunt.

This form, while much like *varians* in coloration, is smaller, less robust, and has genitalia quite distinct from the latter species. It occurs on willow at quite high altitudes (10,000 ft.) in southern Colorado. Specimens are also at hand from California, Oregon, Washington, British Columbia, and Alaska.

HOLOTYPE, female, and ALLOTYPE, male, Spring Creek Pass, Colorado, June 29, 1937, L. D. Tuthill. Numerous PARATYPES with the same data and also from the localities listed above. Holotype, allotype, and paratypes in author's collection; paratypes in United States National Museum and Snow Collection, University of Kansas.

*Trioza rubra*\* Tuthill

(Figs. 212, 213, 213a, 303)

1939 *Trioza rubra* Tuthill, Ia. St. Coll. Jour. Sci. 13:185.

Length to tip of folded wings 3.75 mm.

COLOR: General color red to almost black, males darker in general. Distal portions of legs lighter. Antennae white except distal third black.

STRUCTURE: Vertex almost plane, bulging in front, medial suture prominent. Genal processes large, divergent, blunt,  $\frac{2}{3}$  as long as vertex. Antennae almost twice as long as width of head, basal portion somewhat swollen. Thorax weakly arched. Pronotum short, depressed below plane of vertex. Forewings rather bluntly angled, almost 3 times as long as wide. Hind tibia with large serrate carina basally, two inner apical spines. Metacoxa developed anteriorly as blunt process.

GENITALIA: Male proctiger with rather sharp caudally projecting lobes, surrounding forceps. Forceps large at base, tapering to long slender black-tipped apices, curving cephalad throughout their length; in caudal view broad basally, lateral margins straight, mesal margins bearing

\* *rubrus* -a -um, L. adj.—red.

a triangular tooth midway, apices acute. Female genital segment short, about  $\frac{1}{3}$  as long as rest of abdomen, dorsal valve somewhat concave, black apically, slightly longer than ventral.

Specimens are at hand from Colorado, New Mexico, Arizona, and Oregon.

TYPE, female, Creede, Colorado, in author's collection.

*Trioza lobata*\* Crawford

(Figs. 182, 183, 253)

1914 *Trioza lobata* Crawford, U. S. Nat. Mus., Bull. 85:76, 86.

1917 *Trioza lobata* Van Duzee, Cat. Hemip. N. Am. 795.

1931 *Trioza lobata* Klyver, Pan-Pac. Ent. 7:143.

Length to tip of folded wings 3.25 to 3.5 mm.

COLOR: General color yellow to yellowish brown. Abdomen green ventrally. Tip of each antennal segment dark. Forewings with irregular brown maculae as follows: a broad vitta extending from anal margin between apex of clavus and  $Cu_2$  obliquely to basal angle of costa, another following margin from center of cubital cell across apex; a third arising at tip of Rs extending to cubital cell. Maculae with darker brown dots.

STRUCTURE: Head broad, somewhat deflexed, narrower than thorax, with hairlike pubescence. Vertex flat with two prominent discal impressions, produced anteriorly each side of median ocellus. Genal processes short, very strongly divergent, rounded, parallel with and not much below plane vertex,  $\frac{1}{2}$  as long as vertex including antero-lateral portion. Antennae slightly less than twice as long as width of head. Thorax strongly arched, sparsely pubescent. Pronotum depressed below plane of vertex. Forewings short and broad, less than  $2\frac{1}{2}$  times as long as broad, bluntly angulate. Hind tibia with serrate basal carina, two inner apical spines. Metacoxa with stout spiniform process anteriorly.

GENITALIA: Male genital segment small. Proctiger short, produced into two long attenuate lobes. Forceps about as long as proctiger; in lateral view rather broad basally, constricted midway, apices enlarged; in caudal view broad at base, tapering and arched to acute apices. Female genital segment short; ventral valve very short, apically produced as a large black tooth; dorsal valve strongly curved downward, apex black, beak-like.

Crawford records the type series of this very distinctive species as taken on "a species of *Ceanothus*." Klyver lists one specimen from *Chrysothamnus*. Specimens are at hand from Mojave, Mint Canyon, Tehachapi, and Los Angeles, California; Santa Rita Mountains, Arizona; Organ, New Mexico, and Rattlesnake Buttes in eastern Colorado.

TYPE, male, No. 18086 United States National Museum.

Type examined.

\* From *lobus* -i, Gr. noun—lobe; adjectival form—lobed.

*Trioza tripunctata*\* (Fitch)

(Figs. 184, 185, 267)

- 1851 *Psylla tripunctata* Fitch, 4th Rept. N. Y. Mus. 64.  
 1869 *Psylla rubi* Walsh and Riley, Am. Ent. 1:225.  
 1879 *Psylla rubi* Thomas, 8th Rept. St. Ent. Ill., 3:17-18.  
 1880 *Psylla tripunctata* Fuller and Riley, Am. Ent. 3:62.  
 1885 *Trioza tripunctata* Riley, Proc. Biol. Soc. Wash. 2:70.  
 1893 *Psylla tripunctata* Fitch, (Reprinted in Lintner's 46th report, N. Y. State Museum, p. 404).  
 1894 *Trioza tripunctata* Mally, Proc. Ia. Acad. Sci. 2:154.  
 1910 *Trioza tripunctata* Crawford, Pom. Coll. Jour. Ent. 2:231, 232.  
 1910 *Trioza tripunctata* Smith, Ins. N. J. 110.  
 1911 *Trioza tripunctata* Crawford, Pom. Coll. Jour. Ent. 3:424, 429, 430.  
 1912 *Trioza tripunctata* Patch, Me. Agr. Exp. Sta., Bull. 202:230.  
 1913 *Trioza tripunctata* Aulmann, Psy. Cat. 55.  
 1914 *Trioza tripunctata* Crawford, U. S. Nat. Mus., Bull. 85:87.  
 1917 *Trioza tripunctata* Van Duzee, Cat. Hemip. N. Am. 795.  
 1918 *Trioza tripunctata* McAtee, Ent. News 29:223.  
 1920 *Trioza tripunctata* Crawford, Ent. News 31:70.  
 1923 *Trioza tripunctata* Patch, Hemip. Conn. 245.  
 1923 *Trioza tripunctata* Peterson, N. J. Agr. Exp. Sta., Bull. 378 (Bibliog.).  
 1926 *Phyllopecta tripunctata* Ferris, Can. Ent. 58:18.  
 1938 *Trioza tripunctata* Brimley, Ins. N. C. 103.  
 1938 *Phyllopecta tripunctata* Caldwell, Ohio Biol. Surv., Bull. 34:248.

Length to tip of folded wings 3.5 to 4 mm.

COLOR: General color yellow to brown. Tip of antennae dark. Forewings marked with brown vittae as follows: along distal half of Rs, along M and including cell M<sub>2</sub>, along Cu and including cell Cu<sub>1</sub>, latter two continuous at margin, also a spot on anal vein.

STRUCTURE: Head large, somewhat deflexed. Vertex platelike with very broad shallow discal impressions. Genal processes large, subacute, parallel to plane of vertex, between  $\frac{1}{2}$  and  $\frac{2}{3}$  as long as vertex. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax broad, strongly arched. Pronotum depressed below plane of vertex. Forewings broad, about  $2\frac{1}{4}$  times as long as wide, angulate; Rs long, sinuate, marginal cells very short and broad. Hind tibia with basal spur, two inner apical spines. Metacoxa with anterior portion produced as blunt process.

GENITALIA: Male genital segment of medium size. Proctiger short, produced into two, long, distally rounded lobes. Forceps as long as proctiger, evenly narrowed to acute apices curved cephalad, scarcely arched. Female genital segment about  $\frac{1}{2}$  as long as rest of abdomen; dorsal valve excavate on dorsal margin, somewhat longer than ventral, latter straight, both acute, black-tipped.

One of the first species of psyllids to receive attention in North America was this "bramble flea-louse" or "blackberry psyllid." It has attracted considerable attention in the eastern part of the United States as a pest on blackberries. Peterson's paper (1923) is a most complete account of the damage, life history, and control. It includes figures of the various stages and a complete bibliography up to 1923. The common blackberry (*Rubus*) is the summer host, and Peterson apparently proved

\* From tri-, L. prefix—three + punctatus, L. (p. part. of pungo)—punctured.

that coniferous trees are an essential host for the overwintering females. There is but one generation per year. Specimens are at hand from South Carolina, Maryland, New Hampshire, and Minnesota. It has also been recorded as occurring in Virginia, District of Columbia, New York, Connecticut, Maine, New Jersey, Ontario, Florida, North Carolina, Ohio, Michigan, and probably occurs throughout all the eastern portion of North America wherever *Rubus* and conifers occur together.

TYPE, No. 1345 United States National Museum, male and female on one pin.

Types examined.

*Trioza californica*\* Crawford

(Fig. 269)

1910 *Trioza californica* Crawford, Pom. Coll. Jour. Ent. 2:232, 234.

1911 *Trioza californica* Crawford, Pom. Coll. Jour. Ent. 3:492.

1913 *Trioza californica* Aulmann, Psy. Cat. 40.

1914 *Ceropsylla californica* Crawford, U. S. Nat. Mus., Bull. 85:102.

1914 *Trioza ichneumonina* Crawford, U. S. Nat. Mus., Bull. 85:103.

1917 *Ceropsylla californica* Van Duzee, Cat. Hemip. N. Am. 798.

Length to tip of folded wings 4 mm.

COLOR: General body color orange to brown. Head darker, especially genal processes almost black. Abdominal sternites, basal third of antennae, distal portions of legs light. Veins R + M + Cu, R, anal margin basally, and adjacent membranes heavily embrowned.

STRUCTURE: Head of medium size, narrower than thorax. Vertex plane with broad discal impressions. Genal processes large, straight, subacute, only slightly divergent, barely shorter than vertex. Antennae slightly less than twice as long as width of head. Eyes protruding rather more than usual. Thorax strongly arched. Anterior margin of pronotum depressed below plane of vertex. Forewings about 2½ times as long as wide, acute at apex; Rs short. Hind tibia with two inner apical spines, large serrate basal spur. Anterior portion of metacoxa slightly produced.

GENITALIA: Male genital segment small. Proctiger short, with long, blunt posterior lobes. Forceps large at base, slender and laterally flattened abruptly at about half their length, apical third curved cephalad, apices acute. Female genital segment very short, dorsal valve slightly longer than ventral, acute.

This species is represented in the material before me by several specimens from Southern California and one from Gila County, Arizona. Crawford also records it from Colorado on *Salix*. He placed this species in the genus *Ceropsylla* on the basis of a tendency toward a petiolate condition of M and Cu in the forewings. This petiole is very slight or entirely wanting in the specimens I have examined. It is quite unlike *C. sideroxyli* in head and thoracic characters, and even in wing venation it is more typically triozone; hence, I am referring it back to *Trioza*.

TYPE, male, mountains near Claremont, California, Baker, is in the Crawford Collection.

\* Adjectival form of California.



*Trioza phoradendri*\* Tuthill

(Figs. 214, 215, 304)

1939 *Trioza phorodendrae* Tuthill, Ia. St. Coll. Jour. Sci. 13:182.

Length to tip of folded wings 2.5 mm.

COLOR: Uniformly yellow except eyes, tip of female genital segment, ovipositor and margins of male forceps, black. Forewings yellowish, veins yellow.

STRUCTURE: Vertex somewhat rounding. Genal processes acute, slightly divergent,  $\frac{2}{3}$  as long as vertex, pubescent. Antennae about as long as width of head. Thorax scarcely arched. Pronotum moderately long, depressed below plane of vertex. Legs short. Hind tibia with large basal spur, three inner apical spines. Forewings small, narrowly rounded apically, almost 3 times as long as wide; marginal cells small, Rs very long.

GENITALIA: Male proctiger quite broad, posterior margin curved, anterior margin straight. Forceps in lateral view curving cephalad; "folded" so as to appear double in apical half from caudal view, lateral folds evenly narrowed to apices, medial folds with heavy, black, truncate apices, bearing many, very heavy, medially projecting setae basally. Female genital segment as long as rest of abdomen, rounded, produced at apex into a brown styliform portion, at least tip of ovipositor protruding.

Known only from the type series and one additional female all from Mesa Verde National Park, Colorado. Host *Phoradendron juniperinum* Engelm. The original spelling of the name as *phorodendrae* was an error of transcription and should be *phoradendri*, as above.

TYPE, male, in author's collection.

*Trioza phoradendri acuminata*† n. subsp.

Similar to typical subspecies but apparently greenish in color (the specimen at hand is old and therefore quite faded). Head smaller and narrower proportionately. Genal processes fully as long as vertex, slightly divergent, acute. Antennae  $1\frac{1}{3}$  times as long as width of head. Male genitalia similar.

HOLOTYPE, male, Los Angeles County, California, May, collected on "*Phorodendron pubescens*," No. 55182 United States National Museum.

The genitalia are somewhat obscured on the one specimen at hand but seem to be very much like the typical form. This may be a distinct species, but until more material is available to certify such an opinion I prefer to consider it as a subspecies.

\* Genitive of *Phoradendron*—the generic name of the host.

† *acuminatus*, L. (p. part. of *acumino*)—sharpened.



*Trioza bakeri*\* Crawford

(Figs. 186, 187, 252)

- 1910 *Trioza bakeri* Crawford, Pom. Coll. Jour. Ent. 2:230, 235.  
 1911 *Trioza bakeri* Crawford, Pom. Coll. Jour. Ent. 3:424, 428.  
 1911 *Trioza montana* Crawford, Pom. Coll. Jour. Ent. 3:631.  
 1913 *Trioza bakeri* Aulmann, Psy. Cat. 39.  
 1914 *Trioza bakeri* Crawford, U. S. Nat. Mus., Bull. 85:77.  
 1914 *Trioza puberula* Crawford, U. S. Nat. Mus., Bull. 85:78.  
 1917 *Trioza bakeri* Van Duzee, Cat. Hemip. N. Am. 792.  
 1932 *Trioza bakeri* Klyver, Ent. News 43:35.

Length to tip of folded wings 4 to 4.5 mm.

COLOR: Variable from yellow to brown, tip of antennae black, abdomen of female green when alive. Variable brown markings on dorsum. Wings hyaline.

STRUCTURE: Head large, almost as broad as thorax. Vertex plane, rectangular, discal foveae and medial suture prominent. Genal processes on approximately same plane as vertex. Antennae about as long as width of head. Thorax broad and flat for genus. Pronotum large, not depressed below vertex. Forewings about  $2\frac{2}{3}$  times as long as wide, acutely angled; Rs long and sinuate. Hind tibia with serrate basal tubercle, three inner apical spines. Metacoxa with short, stout, anterior process.

GENITALIA: Proctiger of male produced caudad as a blunt triangle, widest basally, with truncate apex. Forceps shorter than proctiger; in lateral view almost straight; in caudal view arched to black-margined apices, posterior edge produced as blunt tooth. Female genital segment large,  $\frac{1}{2}$  as long as rest of abdomen in fresh specimens, about as long as rest of abdomen in dried specimens, valves straight, equal in length.

Described and recorded heretofore only from California, this species has been taken on *Pinus abies*, *Arctostaphylos*, pear. In 1938 (July 19) I swept numerous specimens from *Rhamnus smithii* Green near Pagosa Springs, Colorado. Since the bushes upon which they occurred were quite isolated and teneral specimens occur in the series, I believe this shrub to be the host plant. Unfortunately, I did not determine whether or not nymphs were present.

TYPE, male, Claremont, California, Baker, in Crawford Collection. Colorado specimens compared with type.

*Trioza brevi antennata*† Crawford

- 1914 *Trioza brevi antennata* Crawford, U. S. Nat. Mus., Bull. 85:75, 78.  
 1917 *Trioza brevi antennata* Van Duzee, Cat. Hemip. N. Am. 792.  
 1932 *Trioza brevi antennata* Klyver, Ent. News 43:35.

Crawford describes this species as similar to *Trioza bakeri* but differing in color, pubescence, punctuation, and in minor details of structure. I do not believe that these differences are of specific value as Crawford describes them, but as I have seen none of the specimens on which the

\* Named in honor of C. F. Baker.

† From *brevis* -e, L. adj.—short + adjectival form of *antenna*.

species was based, I hesitate to throw it into synonymy. His description follows:

"Very similar in size and general proportions to *T. bakeri*; wings relatively a little shorter. General color light to dark brown, often very dark; legs and antennae lighter, except latter black at tip; in light forms the vertex is dark brown to black. Vertex and dorsum not pubescent as in *bakeri*, but very coarsely punctate.

"Similar in many respects to *bakeri*, but vertex very conspicuously bulging on each side of median line; genal cones relatively shorter; antennae a little shorter, scarcely as long as width of head. Thorax as in *bakeri*, but not pubescent. Hind tibiae with three apical spines within. Wings large, resembling *bakeri*.

"*Genitalia: Male*—Anal valve as in *bakeri*, but base of triangle shorter; forceps similar, subacute at apex, sides almost parallel. *Female*—Genital segment similar, but dorsal valve a little longer than ventral.

"Described from two males and one female from Claremont, California (mountains), collected by C. F. Baker, no data with them."

TYPE in Crawford Collection.

*Trioza (Megatrioza) \* diospyri*† (Ashmead)

(Figs. 188, 189, 254)

- 1881 *Psylla diospyri* Ashmead, Can. Ent. 13:222.  
 1885 *Trioza diospyri* Riley, Proc. Biol. Soc. Wash. 2:70.  
 1910 *Trioza latipennis* Crawford, Pom. Coll. Jour. Ent. 2:230.  
 1910 *Trioza diospyri* Crawford, Pom. Coll. Jour. Ent. 2:352.  
 1911 *Trioza diospyri* Crawford, Pom. Coll. Jour. Ent. 3:424, 428.  
 1912 *Trioza diospyri* Patch, Me. Agr. Exp. Sta., Bull. 202:226.  
 1913 *Psylla diospyri* Aulmann, Psy. Cat. 14.  
 1914 *Trioza diospyri* Crawford, U. S. Nat. Mus., Bull. 85:78.  
 1917 *Trioza diospyri* Van Duzee, Cat. Hemip. N. Am. 792.  
 1918 *Trioza diospyri* McAtee, Ent. News 29:223.  
 1919 *Megatrioza diospyri* Crawford, Phil. Jour. Sci. 15:193.  
 1926 *Spanioza diospyri* Enderlein, Ent. Mitt. 15:400.  
 1926 *Phyllopecta diospyri* Ferris, Can. Ent. 58:16.  
 1928 *Trioza diospyri* Leonard, Ins. N. Y. 183.  
 1928 *Phyllopecta diospyri* Ferris, Can. Ent. 60:245.  
 1938 *Trioza diospyri* Brimley, Ins. N. C. 103.  
 1938 *Phyllopecta diospyri* Caldwell, Ohio Biol. Surv., Bull. 34:249.

Length to tip of folded wings 4.5 mm.

COLOR: General color shining black. Meso- and metatibiae, all tarsi, genal processes and antennae except tip, whitish.

STRUCTURE: Entire body sparsely clothed with long hairlike setae. Head broad but narrower than thorax. Vertex plane, with slight discal impressions. Genal processes short, about  $\frac{1}{2}$  as long as vertex, rounded, slightly divergent. Antennae about  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Pronotum strongly depressed, entirely below level of vertex. Forewings very large, almost twice as long as body, about

\* From *megas*, Gr. adj.—great, large + *trioza*.

† Genitive of *Diospyros*—the generic name of the host.

2¾ times as long as wide, acutely angled at apex; marginal cells unusually large, especially medial, Rs short, less than ½ total length of wing, straight. Hind wings very small, less than ½ as long as forewings. Legs longer than in most species. Hind tibia with three inner apical spines, without basal spur or carina. Posterior metacoxal spur large, curved. Anterior margin of metacoxa produced into spur, larger than posterior one.

**GENITALIA:** Male genital segment small. Proctiger somewhat longer than forceps, produced caudad as large blunt lobes, anus borne on a prominent epiphysis. Forceps almost straight in lateral view; in caudal view broad, basal ⅔ straight, apical ⅓ curved inward, apices with several small black teeth. Female genital segment of medium size, about ½ as long as rest of abdomen, valves acute, ventral upcurved to meet dorsal, latter longer, entire segment usually pointing ventrad.

This species is quite distinct in many respects from other North American *Trioxa*. It is abundant throughout the range of the common persimmon, *Diospyros virginiana* L., which is its host. Specimens are at hand from the following states: Florida, Georgia, Alabama, Mississippi, Louisiana, Texas, Oklahoma, Kentucky, Tennessee, New Jersey, Iowa. It is also recorded from Missouri, Virginia, North Carolina, Ohio, New York.

Ashmead gives the life history in Florida in some detail:

"By the middle of April this is found in considerable numbers on the leaves of the young trees, with beaks inserted, almost standing on their heads, and swaying from side to side like the motion of a vessel in a stormy sea. This motion is evidently intended to assist either in inserting the beak or in pumping up the juices of the tree.

"At this time they are also caught copulating, soon after which the female begins depositing her eggs. These are very minute, 0.01 inch in length, elongate ovate, pale greenish in color, with a wavy beak beneath at thick end, and a long filament at tip of smaller end, nearly the length of the egg, and extending backwards over it. These are laid along the margin of the leaf, without regard to regularity, the female first preparing for their reception by secreting a threadlike, transparent, gummy substance along the extreme edge of the leaf; she then fastens them in place by the beak, which adheres securely to the gummy substance.

"These hatch in from 5 to 6 days (actual observation) and the leaf from their punctures curls completely over them; under this they reside until just before the final transformation. The pupa then comes forth, attaches itself to a leaf or a twig, and changes into the perfect fly, escaping through a longitudinal slit in the head and thorax. The young take from four to five weeks to mature and breed throughout the whole summer.

"Like the Fig Psylla, the fall brood probably lay their eggs in crevices of the bark and twigs; these hatch at the first breath of spring, feed on the tender new shoots and leaves, and are those found fully matured by the first and second week in April."

The fifth stadium nymph has been described and figured by Ferris (1926).

TYPE, female, No. 14820 United States National Museum, is moldy and in poor condition, but is unmistakable.

Type examined.

*Trioza beameri*\* Tuthill

(Figs. 216, 217, 305)

1939 *Trioza beameri* Tuthill, Ia. St. Coll. Jour. Sci. 13:182.

Length to tip of folded wings 5 mm.

COLOR: General color whitish-yellow except eyes and tips of antennae dark.

STRUCTURE: Entire body pubescent, least prominently on abdomen. Vertex rather flat with two prominent sulcate depressions. Antennae about  $1\frac{1}{3}$  times as long as width of head. Genal processes large, extending forward,  $\frac{3}{4}$  as long as vertex. Thorax not very strongly arched. Pronotum very long, scarcely depressed. Forewings very large, twice as long as body, acute, almost 3 times as long as broad; cubital cell larger than medial. Posterior tibia with serrate carina basally, three inner apical spines. Anterior process of metacoxa scarcely developed.

GENITALIA: Male proctiger in lateral view broad in basal  $\frac{1}{2}$ , then obliquely truncate to apex. Forceps in lateral view almost straight to apices, latter produced caudad as blunt black teeth; caudal view broadest at base, bowed out, evenly narrowed to apices. Female genital segment about as long as rest of abdomen, valves straight to acute apices, dorsal slightly longer than ventral, very pubescent.

Known only from the type series from the San Jacinto Mountains, California.

TYPE, male, in Snow Collection, University of Kansas.

*Trioza chlora*† Tuthill

(Figs. 218, 219, 306)

1938 *Trioza chlora* Tuthill, Ent. News 49:244.

Length to tip of folded wings 3.25 to 3.50 mm.

COLOR: General color white to yellow except eyes and apical  $\frac{2}{3}$  of antennae black. Thoracic dorsum and vertex deeper yellow to orange. Wings hyaline.

STRUCTURE: Head medium in size, post-ocular occipital region very large giving the eyes the appearance of projecting forward. Vertex somewhat rounding, rather deeply emarginate in front, extending forward over front ocellus. Genal processes vertical, about as long as vertex, rather acute. Antennae twice as long as width of head. Thorax strongly arched. Pronotum short, descending, depressed below plane of vertex. Forewings almost 3 times as long as broad, sharply angled; venation typical triozine. Hind tibia with large basal spur, three inner apical spines.

\* Named in honor of R. H. Beamer.

† From *chloros*, Gr. adj.—pale.

**GENITALIA:** Male genitalia small. Proctiger broad at base, tapered to slightly produced apex, bearing a black spine at base on each side. Forceps slightly shorter than proctiger; in lateral view broad, anterior margin almost straight, posterior margin slightly curved, apices roundly truncate and slightly produced anteriorly, apical margin brown. Female genital segment shorter than rest of abdomen, basal portion subglobular, apex a short, brown, styliform elongation; dorsal valve slightly longer than ventral.

HOLOTYPE and ALLOTYPE in the Snow Collection, University of Kansas, are from Arizona and are the only known specimens.

*Trioza proximana*\* Crawford

(Figs. 190, 191)

1911 *Trioza proximana* Crawford, Pom. Coll. Jour. Ent. 3:424, 429, 435.

1914 *Trioza proximana* Crawford, U. S. Nat. Mus., Bull. 85:81.

Length to tip of folded wings 3 to 3.5 mm.

**COLOR:** Testaceous to almost white, perhaps greenish when fresh. Tips of antennae and styliform portion of female genital segment black.

**STRUCTURE:** Head narrower than thorax. Occiput large, posterior margin of eyes opposite lateral ocelli. Vertex with two discal sulci, medial suture deep. Genal processes short, heavy, blunt,  $\frac{1}{2}$  as long as vertex. Antennae twice as long as width of head. Thorax broad, quite strongly arched. Pronotum strongly descending but not at all depressed below plane of vertex. Forewings almost 3 times as long as wide, rounded apically. Hind tibia with large serrate basal tubercle, three inner apical spines.

**GENITALIA:** Male proctiger long, caudal margin arcuately produced, a prominent epiphysis at apex. Forceps long; in lateral view moderately broad, curved cephalad, tapering, apices black, with small black tooth; in caudal view almost straight-sided, slightly arched, a prominent row of setae on inner margins. Female genital segment very long,  $\frac{3}{4}$  as long as remainder of body, proximal  $\frac{1}{3}$  large, tapering distal portion of valves very slender, acuminate and appressed to ovipositor, latter extending somewhat beyond valves; dorsal valve longer than ventral.

A number of specimens are at hand from Ramsey Canyon, Huachuca Mountains, Arizona, October 30, 1937, collected by P. W. Oman, which seem undoubtedly to be this species described from southwestern Mexico. No host plant data are available.

TYPE in Crawford Collection.

*Trioza collaris*† Crawford

(Figs. 192, 193)

1910 *Trioza collaris* Crawford, Pom. Coll. Jour. Ent. 2:229, 347.

1911 *Trioza collaris* Crawford, Pom. Coll. Jour. Ent. 3:424, 429.

\* Apparently from *proximus* -a -um, L. adj.—nearest.

† *collaris* -e, L. adj.—pertaining to the neck.



- 1912 *Trioza collaris* Patch, Me. Agr. Exp. Sta., Bull. 202:225.  
1913 *Trioza collaris* Aulmann, Psy. Cat. 44.  
1914 *Trioza collaris* Crawford, U. S. Nat. Mus., Bull. 85:81.  
1917 *Trioza collaris* Van Duzee, Cat. Hemip. N. Am. 793.  
1932 *Trioza collaris* Klyver, Ent. News 43:35.

Length to tip of folded wings 4 to 4.5 mm.

COLOR: General color green to yellowish green, occasionally with some darker markings on dorsum of thorax. Tips of antennae, styliform portion of female genitalia, and apices of male forceps, dark.

STRUCTURE: Head large, only slightly narrower than thorax. Vertex scarcely plane, discal impressions prominent. Genal processes short, not over  $\frac{1}{2}$  as long as vertex, appressed, blunt to acute. Antennae twice as long as width of head. Thorax large, flat. Pronotum long, strongly descending cephalad, not depressed below vertex. Forewings large, angular at apex, almost 3 times as long as wide. Hind tibia with basal tubercle bearing two small spines, with three inner apical spines. Anterior portion of metacoxa short, stout.

GENITALIA: Male proctiger slightly, roundly produced on caudal margin. Forceps about as long as proctiger, slender, bent cephalad, slightly bowed, apices sharp, black. Female genital segment large, about twice as long as rest of abdomen, about half as long as remainder of body, consisting of a large basal portion and a styliform projection, latter about as long as base, black; basal portion produced ventrally just before constriction.

This species is apparently quite common in California and neighboring states. Klyver gives data indicating *Baccharis* spp. as the probable host. Numerous specimens are at hand from California, Arizona, New Mexico, and El Paso, Texas. Some of these specimens bear labels "collected on *Baccharis viminea*."

TYPE in Crawford Collection.

### *Trioza longistylus*\* Crawford

- 1910 *Trioza longistylus* Crawford, Pom. Coll. Jour. Ent. 2:233.  
1911 *Trioza longistylus* Crawford, Pom. Coll. Jour. Ent. 3:424, 429, 434.  
1912 *Trioza longistylus* Patch, Me. Agr. Exp. Sta., Bull. 202:227.  
1913 *Trioza longistylus* Aulmann, Psy. Cat. 48.  
1914 *Trioza longistylus* Crawford, U. S. Nat. Mus., Bull. 85:82.  
1917 *Trioza longistylus* Van Duzee, Cat. Hemip. N. Am. 793.

An examination of the type (No. 18083 United States National Museum), a female, fails to show any apparently significant difference between this form and *collaris* except that the ventral hump present on the genital segment of the female of *collaris* is lacking. That this is a distinct species is extremely doubtful, but it is retained pending further collection in the type locality.

\* From *longus* -a -um, L. adj.—long + *stylus* -i, L. m. noun—style.



*Trioza mexicana*\* *minor*\*\* n. n.

(Figs. 194, 195)

1911 *Trioza mexicana minuta* Crawford, Pom. Coll. Jour. Ent. 3:424, 429, 440.1914 *Trioza mexicana minuta* Crawford, U. S. Nat. Mus., Bull. 85:80.

Length to tip of folded wings 2.75 to 3.0 mm.

COLOR: General color red. Abdomen darker. Legs and genal processes testaceous.

STRUCTURE: Head large but narrower than thorax. Vertex with medial suture prominent, discal impressions very shallow, rounding in front to genal processes. Latter straight, slender, acute, scarcely divergent,  $\frac{2}{3}$  as long as vertex. Antennae about  $1\frac{1}{4}$  times as long as width of head. Thorax broad, well arched, with very short, sparse pubescence, scarcely visible. Pronotum long, scarcely depressed below vertex. Forewings broad, rounded apically, slightly less than  $2\frac{1}{2}$  times as long as wide, finely punctate. Hind tibia with large basal spur, three inner apical spines.

GENITALIA: Male proctiger roundly produced caudad, with very distinct apical epiphysis. Forceps in lateral view rather broad to near apex then curved cephalad, apices broad, black; in caudal view broad, almost straight, apices incurved, touching, postero-mesal margins with a row of very large heavy setae. Female genital segment longer than rest of abdomen, basal portion large, swollen, apices of valves acuminate, black; prominent short setae on all of basal portion, a tuft of very long setae on dorsal valve at base of acuminate portion.

This insect was described by Crawford from Mexico. Numerous specimens are at hand from southern Arizona and have been compared with the type. Although this subspecies is like the typical form except for slight differences in the genal processes, it is so consistently smaller that it is maintained. The name *minor* is proposed to replace the name *minuta* which is preoccupied by *Trioza minuta* Crawford. Crawford records the typical form as taken on *Rhus* sp.

TYPE (type of *Trioza mexicana minuta* Crawford) in Crawford Collection.

*Trioza quadripunctata*† Crawford

(Figs. 196, 266)

1910 *Trioza quadripunctata* Crawford, Pom. Coll. Jour. Ent. 2:233.1911 *Trioza quadripunctata* Crawford, Pom. Coll. Jour. Ent. 3:425, 429, 433.1912 *Trioza quadripunctata* Patch, Me. Agr. Exp. Sta., Bull. 202:229.1913 *Trioza quadripunctata* Aulmann, Psy. Cat. 51.1914 *Trioza quadripunctata* Crawford, U. S. Nat. Mus., Bull. 85:82.1917 *Trioza quadripunctata* Van Duzee, Cat. Hemip. N. Am. 793.1926 *Spanioza quadripunctata* Enderlein, Ent. Mitt. 15:400.1928 *Trioza quadripunctata* Leonard, Ins. N. Y. 183.\* *mexicana*—the adjectival form of Mexico.\*\* *minor* -us, L. adj. (comp. of *parvus*)—smaller.† From *quadri*, L. comb. form—four + *punctatus*, L. (p. part. of *pungo*)—punctured.

1938 *Trioza quadripunctata* Caldwell, Ohio Biol. Surv., Bull. 34:247.

1938 *Trioza quadripunctata* Strickland, Can. Ent. 70:204.

1939 *Trioza quadripunctata* Strickland, Can. Ent. 71:214.

Length to tip of folded wings 4 mm.

COLOR: General color of summer form greenish-white to yellowish, winter form darker, brownish. Apical  $\frac{1}{2}$  of antennae and tips of tarsi black. Hind margin of forewing with four black spots, three distal ones coinciding with radular areas typical for genus, remainder of wing hyaline or somewhat milky.

STRUCTURE: Head small, narrower than thorax. Vertex with prominent discal impressions, anterior margin produced, overhanging. Genal processes short, stout, divergent, about  $\frac{1}{2}$  as long as vertex. Antennae twice as long as width of head. Thorax strongly arched. Pronotum long, anterior margin below plane of vertex. Forewings short, slightly less than  $2\frac{1}{2}$  times as long as wide, costal margin rounded, apex scarcely angulate, Rs short, straight. Hind tibia without basal armature, with three inner apical spines.

GENITALIA: Male proctiger arcuately produced caudad, an apical epiphysis. Forceps long, slender; in lateral view straight; in caudal view strongly arched to acute black apices. Female genital segment  $\frac{2}{3}$  as long as rest of abdomen, valves straight, acute, dorsal slightly longer than ventral, black-tipped.

Numerous specimens of this nettle- (*Urtica*) inhabiting species are at hand from the following localities: Minnesota, Iowa, Missouri, Kansas, Colorado, and Wyoming. It is also recorded from California, Montana, Alberta, Ohio, and New York. It is very much like *albifrons* but can readily be distinguished from it by the dark maculae in the forewings. This may be simply a variety of *albifrons*, but it seems doubtful from collecting and distributional data. I have swept great numbers of *albifrons* in Colorado and Minnesota without finding a single specimen of *quadripunctata*; in Iowa pure populations of *quadripunctata* have been observed.

TYPE, male, No. 18084 United States National Museum.

Type examined.

### *Trioza albifrons*\* Crawford

(Figs. 3, 197, 198)

1910 *Trioza albifrons* Crawford, Pom. Coll. Jour. Ent. 2:231, 355.

1910 *Trioza rotundipennis* Crawford, Pom. Coll. Jour. Ent. 2:231, 236.

1910 *Trioza similis* Crawford, Pom. Coll. Jour. Ent. 2:231, 352.

1910 *Trioza fovealis* Crawford, Pom. Coll. Jour. Ent. 2:233.

1911 *Trioza albifrons* Crawford, Pom. Coll. Jour. Ent. 3:426, 429, 438.

1911 *Trioza rotundipennis* Crawford, Pom. Coll. Jour. Ent. 3:425, 427.

1911 *Trioza similis* Crawford, Pom. Coll. Jour. Ent. 3:426, 428.

1911 *Trioza similis fovealis* Crawford, Pom. Coll. Jour. Ent. 3:426, 428, 438.

1913 *Trioza albifrons* Aulmann, Psy. Cat. 39.

1913 *Trioza fovealis* Aulmann, Psy. Cat. 46.

1913 *Trioza rotundipennis* Aulmann, Psy. Cat. 52.

\* From *albus* -a -um, L. adj.—white + *frons frontis*, L. f. noun—forehead.

- 1913 *Trioza similis* Aulmann, Psy. Cat. 55.  
1914 *Trioza albifrons* Crawford, U. S. Nat. Mus., Bull. 85:83.  
1917 *Trioza albifrons* Van Duzee, Cat. Hemip. N. Am. 793.  
1930 *Trioza albifrons* Klyver, Can. Ent. 62:169.  
1932 *Trioza albifrons* Klyver, Ent. News 43:36.  
1938 *Trioza similis* Strickland, Can. Ent. 70:204.

Length to tip of folded wings 3 to 3.5 mm.

COLOR: General color from green to light yellow through brown to black. In lighter forms only eyes, distal  $\frac{1}{2}$  of antennae, and last segment of tarsi, dark. In dark forms, rim of vertex, male genitalia and usually legs, light. (Between these extremes all variations in color occur.)

STRUCTURE: Head small, narrower than thorax. Disc of vertex depressed, edges carinate, protruding in front. Genal processes acute, divergent, on approximately parallel plane to vertex, about  $\frac{2}{3}$  as long as vertex. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Pronotum depressed below plane of vertex. Forewings varying from angular to round apically; Rs rather short to long. Hind tibia without basal armature, with three inner apical spines.

GENITALIA: Male proctiger slightly longer than forceps, basal  $\frac{3}{4}$  roundly produced. Forceps stout, arched to heavy, apparently black-tipped apices (see Klyver, 1930), anterior margins excavate near apices. Female genital segment  $\frac{1}{2}$  to  $\frac{2}{3}$  as long as rest of abdomen, valves approximately equal in length, almost straight to usually sharp apices, somewhat rounded in some specimens.

Crawford states that there are sometimes only two inner apical spines on the hind tibia instead of three. I have examined several hundred specimens from various localities and have seen this condition on only two specimens, one collected by Crawford at Stanford University and one other. In both these specimens one tibia bears three spines and the other only two. This condition I believe to be only an aberration of such infrequent occurrence as to be of no significance.

I have examined Crawford's types (?) of *similis* and *rotundipennis* which are in the National Museum (specimens with red labels) and find them to be *albifrons*. The type of *similis fovealis* is a malformed specimen.

This is apparently a widely distributed species of western North America. Numerous specimens have been examined from the following localities: California, Oregon, Washington, British Columbia, Alaska, Idaho, Utah, Montana, Colorado, Arizona, New Mexico, and Minnesota. Strickland records it (*similis*) from Alberta. It occurs in large numbers on various species of *Urtica*. As would be expected in such a widespread species, there is considerable minor variation in characters.

TYPE, a male from Claremont, California, is in the Crawford Collection.

Crawford (1914) gives a general description of the egg and nymph together with some biological notes. Klyver (1930) compares *albifrons* with *urticae* in detail, describes and figures the nymph of the former.

*Trioza sembla*\* Caldwell

(Fig. 220)

1940 *Trioza sembla* Caldwell, Ohio Jour. Sci. 40:49.

"Length to tip of forewing 2.7 mm.; forewing 2.2 mm.

"Color: Light orange except for black eyes, black antennae beyond second segment, brown tarsi, and yellow margin around vertex.

"Head as broad as thorax, both finely pubescent. Genal cones  $\frac{2}{3}$  as long as vertex, acute, slightly divergent. Antennae a little longer than width of head. Forewings little over twice as long as broad; apices subacute.

"Proctiger of male with large caudal lobes. Forceps shorter than proctiger. In lateral aspect: Caudal margin practically straight, cephalic margin slightly produced cephalad, apices slightly rounded rather than truncate. In caudal aspect: thick basally, slightly bowed, narrowed evenly to apices.

"Male holotype, Painted Desert, Arizona, VI-25, D. J. and J. N. Knull, collectors, is in the Ohio State University Collection."—Caldwell.

I have not seen the specimen on which this species is based. Caldwell has supplied me with the additional information that there are three inner apical spines on the hind tibia.

*Trioza frontalis*† Crawford

(Figs. 199, 200, 201, 271)

1910 *Trioza frontalis* Crawford, Pom. Coll. Jour. Ent. 2:230, 353.1911 *Trioza frontalis* Crawford, Pom. Coll. Jour. Ent. 3:426, 429, 436.1913 *Trioza frontalis* Aulmann, Psy. Cat. 46.1914 *Trioza frontalis* Crawford, U. S. Nat. Mus., Bull. 85:84.1917 *Trioza frontalis* Van Duzee, Cat. Hemip. N. Am. 794.1926 *Spanioza frontalis* Enderlein, Ent. Mitt. 15:400.1932 *Trioza frontalis* Klyver, Pan-Pac. Ent. 8:14.1932 *Trioza frontalis* Klyver, Ent. News 43:36.1939 *Trioza frontalis* Strickland, Can. Ent. 71:214.

Length to tip of folded wings 3.5 mm.

COLOR: General color orange red to brown. Antennae, genal processes, and abdomen darker.

STRUCTURE: Head large, deflexed. Vertex broad, discal foveae and medial suture prominent, front margin abrupt. Genal processes acute, divergent,  $\frac{2}{3}$  as long as vertex at middle, on parallel plane with vertex. Antennae rather heavy,  $1\frac{1}{2}$  times as long as width of head. Thorax not very strongly arched. Pronotum narrow, depressed. Forewings about  $2\frac{1}{2}$  times as long as wide, apices subacute. Hind tibia with small serrate carina basally, three inner apical spines. Metacoxa only slightly produced anteriorly.

GENITALIA: Male genitalia large. Proctiger longer than forceps, produced caudad as large lobes with dorsal margins slightly upcurved,

\* A barbaric name.

† Apparently based on the latin *frons*—forehead.

apices blunt. Forceps large; in lateral view stalk slender, straight, apical portion evenly enlarged; in caudal view slightly arched; apices excavate on mesal margins, anterior portion more or less of a truncate tooth. Female genital segment large, almost as long as rest of abdomen; ventral valve upcurved, acute; dorsal valve longer than ventral, apical portion attenuate, blunt.

This species is quite typical of a number of *Amelanchier*-inhabiting forms all of which have quite massive heads, large bodies, and are more or less powdered with a waxy bloom as adults.

Specimens are at hand from the following localities: California, British Columbia, Manitoba, Minnesota, North Dakota, South Dakota, and Colorado. It has also been recorded from Nevada.

Many of the California specimens (including nymphs) bear the label *Amelanchier alnifolia* which Klyver also records as the host. The California specimens show some variation from those taken in Colorado but not a significant difference.

TYPE, male, No. 18085 United States National Museum.

Type examined.

### *Trioza sulcata*\* Crawford

(Figs. 221, 222, 307)

1910 *Trioza sulcata* Crawford, Pom. Coll. Jour. Ent. 2:233.

1910 *Trioza sulcata similis* Crawford, Pom. Coll. Jour. Ent. 2:233.

1911 *Trioza frontalis sulcata* Crawford, Pom. Coll. Jour. Ent. 3:426, 429, 436.

1913 *Trioza sulcata* Aulmann, Psy. Cat. 55.

1913 *Trioza sulcata similis* Aulmann, Psy. Cat. 55.

1914 *Trioza frontalis sulcata* Crawford, U. S. Nat. Mus., Bull. 85:85.

1917 *Trioza frontalis sulcata* Van Duzee, Cat. Hemip. N. Am. 794.

1938 *Trioza frontalis sulcata* Strickland, Can. Ent. 70:203.

Length to tip of folded wings 3 mm.

COLOR: General color most typically orange with black tarsi and antennae. Often much darker with brown markings on vertex and thorax, abdomen, femora, etc., dark. Frequently with a wax bloom.

STRUCTURE: Head large, almost as wide as thorax. Vertex with two sulcate impressions. Genal processes slender, straight, acute, divergent from base, about  $\frac{4}{5}$  as long as vertex. Antennae about  $1\frac{2}{3}$  times as long as width of head. Thorax strongly arched, often with short sparse pubescence. Pronotum depressed below plane of vertex. Forewings slender,  $2\frac{3}{4}$  times as long as wide. Hind tibia with small serrate carina basally, three inner apical spines. Anterior portion of metacoxa enlarged, prominent.

GENITALIA: Male genitalia large. Proctiger produced caudally from base to apex, dorsal margin straight, crenellated, ventral margin upcurved. Forceps in lateral view very broad, parallel-sided, apically curved cephalad, apices with a slight notch; in caudal view straight, broad basally, tapered to sharp apices. Female genital segment short, about  $\frac{1}{2}$  as long

\* *sulcatus*, L. (p. part. of *sulco*)—furrowed.



as abdomen; ventral valve strongly upcurved, acute; dorsal valve slightly longer, blunt.

Crawford originally separated this species from *frontalis* because of the more divergent genal processes and the deeper sulci on the vertex. Subsequently, he decided these differences were insufficient to constitute a species and maintained it as a variety chiefly on color. Unfortunately he had no males, the genitalia of which are quite distinct from *frontalis*. The type specimen is a dark-colored individual, but a majority of the specimens at hand are of an orange-red color. They were taken on *Amelanchier* sp. in the arid portions of southwestern Colorado.

Specimens are at hand from the following localities: Durango and Mesa Verde, Colorado; Arizona; Utah; Nevada; California; Oregon. Strickland records it from Alberta (?).

HOLOTYPE, female, Colorado, C. F. Baker, No. 55183 United States National Museum. ALLOTYPE, male, Durango, Colorado, July 4, 1937, L. D. Tuthill, in the United States National Museum.

Type examined.

*Trioza mira*\* n. n.

(Figs. 223, 224)

1939 *Trioza forcipula* Tuthill, Ia. St. Coll. Jour. Sci. 13:183.

[non] *Trioza forcipula* Patch, Me. Agr. Exp. Sta., Bull. 202:227. 1912.

Length to tip of folded wings 3 mm.

COLOR: Dorsum orange-red except center of abdominal tergites, two incomplete lines on thorax, discal foveae and medial suture of vertex and antennae black. Venter black except tip of genal processes and tibiae.

STRUCTURE: Head wide, almost as wide as thorax. Discal foveae and medial suture of vertex prominent. Genal processes  $\frac{2}{3}$  as long as vertex. Antennae slightly over  $1\frac{1}{4}$  times as long as width of head. Thorax weakly arched. Pronotum short, strongly descending, depressed below plane of vertex. Forewings a little more than twice as long as wide, rather bluntly angled. Hind tibia with very small basal spur, three inner apical spines. Metacoxa slightly produced anteriorly as very broad flat process.

GENITALIA: Proctiger of male with very long, upcurved, posterior lobes, with a prominent apical tuft of spines. Forceps bent forward and also inward, touching most of their length, apices deeply notched, anterior tooth larger. Female genital segment short, almost globose in lateral aspect, apices of valves black; dorsal valve slightly produced; ventral valve truncate and concave about ovipositor.

In addition to the type series from Colorado and Washington, additional specimens are at hand from scattered points in Colorado and Utah. As do the foregoing and following species, this form inhabits *Amelanchier*.

TYPE, male, in author's collection.

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\* *mirus* -a -um, L. adj.—extraordinary.



*Trioza mira curta*\* n. subsp.

Similar to species except male genitalia. Caudal lobes on proctiger much shorter, forceps not incurved and touching, apical notch much shallower. Female genitalia similar to typical subspecies.

Described from seven specimens from Placer and Nevada Counties, California, September, collected by A. Koebele, all of which are somewhat teneral and are faded, the thoracic markings of the typical subspecies show faintly, however.

HOLOTYPE, male, ALLOTYPE, female, (same mount) No. 55184 United States National Museum, Lake Tahoe, Placer County, California, September 30, 1885; five female PARATYPES, one additional male (doubtful) Placer and Nevada Counties, California; one of the paratypes bears the label *Amelanchier alnifolia* Nutt. Holotype, allotype, and paratypes in the United States National Museum; paratypes in author's collection.

*Trioza inversa*† Tuthill

(Figs. 225, 226, 308)

1939 *Trioza inversa* Tuthill, Ia. St. Coll. Jour. Sci. 13:185.

Length to tip of folded wings 3 mm.

COLOR: General color of dorsum ferrugineous with a pair of fuscous markings on vertex, a pair on scutum, another pair on scutellum. Venter, femora, and antennae fuscous, remainder fulvous. Wings hyaline.

STRUCTURE: Head broad, almost as wide as thorax. Genal processes long, quite sharp, projecting downward,  $\frac{4}{5}$  as long as vertex. Antennae  $1\frac{1}{3}$  times as long as width of head. Thorax moderately arched. Pronotum short, not depressed below plane of vertex. Forewings only slightly angulate, almost 3 times as long as wide. Hind tibia with small basal spur, three inner apical spines. Metacoxa with anterior process moderately developed.

GENITALIA: Proctiger with a basal caudal projection, apex very narrow. Forceps in lateral view large at base, narrowed to spatulate apices; in caudal view broad at base, laterally concave to apices, touching most of their length. Female genital segment about  $\frac{1}{2}$  as long as remainder of abdomen, acute, dorsal valve slightly longer than ventral.

This *Amelanchier*-inhabiting species was described from specimens from Colorado, Utah, and British Columbia and is no doubt much more widespread in distribution.

TYPE, male, in author's collection.

*Trioza obtusa*‡ Patch

(Figs. 202, 203)

1911 *Trioza obtusa* Patch, Me. Agr. Exp. Sta., Bull. 187:18.

1914 *Trioza obtusa* Crawford, U. S. Nat. Mus., Bull. 85:85.

\* *curtus* -a -um, L. adj.—short.

† *inversus* -a -um, L. adj.—turned inside out.

‡ *obtusus* -a -um, L. adj.—blunt, obtuse.

- 1917 *Trioza obtusa* Van Duzee, Cat. Hemip. N. Am. 795.  
1918 *Trioza obtusa* McAtee, Ent. News 29:223.  
1932 *Trioza obtusa* Klyver, Ent. News 43:36.  
1938 *Trioza obtusa* Brimley, Ins. of N. C. 103.

Length to tip of folded wings 4 mm.

COLOR: General color ranging from green in newly emerged adults to red and reddish brown. Typically colored individuals, orange-red, antennae, genal processes, femora, and genitalia darker, often with anterolateral margins of prescutum dark. Wings from transparent to brownish opaque.

STRUCTURE: Head large, almost as wide as thorax. Vertex with medial suture prominent and very deep discal foveae, posterior margin raised. Genal processes heavy, sharp,  $\frac{2}{3}$  as long as vertex, apices divergent. Antennae short, about  $1\frac{1}{3}$  times as long as width of head. Thorax broad, well arched. Pronotum depressed below plane of vertex. Forewings very bluntly angulate,  $2\frac{1}{2}$  times as long as wide; Rs very long. Hind tibia with prominent, serrate, basal carina, three inner apical spines. Metacoxa somewhat produced anteriorly.

GENITALIA: Male genital segment of medium size. Proctiger with large caudal lobes, latter as long as axial portion, ventral margin of lobes almost straight, apices narrow but blunt, setae prominent, especially on dorsal margin of lobes. Forceps shorter than proctiger, very heavy; in lateral view enlarged at apices, apices notched on mesal margin to form two black tooth-like lobes. Female genital segment large, about as long as rest of abdomen; ventral valve upcurved to black, acute apex; dorsal valve longer than ventral, attenuate, tip blunt.

This form, while much like *Trioza frontalis*, is even more robust of head and body, the forewings are more rounded apically and are more or less brown, in hibernating forms very dark.

Specimens are at hand from the following localities: Raquette Lake and White Face Mountain, New York; Washington, D. C.; Maryland; Alabama (taken on pine in February, Schwarz); Park Rapids, Minnesota. The Minnesota specimens (including nymphs) were taken from *Amelanchier* sp. in company with *Trioza frontalis* (August 1), apparently the ranges of the two species overlap in this region. Additional records are Maine, Nova Scotia, and North Carolina.

Host *Amelanchier* sp.

TYPES (lost?), Orono, Maine.

Miss Patch briefly described the nymphs and gave a few life history notes.

#### *Trioza aylmeriae*\* Patch

- 1912 *Trioza aylmeriae* Patch, Me. Agr. Exp. Sta., Bull. 202:225.  
1914 *Trioza aylmeriae* Crawford, U. S. Nat. Mus., Bull. 85:93.  
1914 *Trioza aylmeriae* Crawford, U. S. Nat. Mus., Bull. 85:86.  
1917 *Trioza aylmeriae* Van Duzee, Cat. Hemip. N. Am. 797.

\* Genitive of Aylmer, name of a town in Ontario—the point of collection of the originally described specimens.

1918 *Trioza aylmeriae* McAtee, Ent. News 29:223.

1938 *Neotrioza virginiana* Caldwell, Ohio Biol. Surv., Bull. 34:254.

1939 *Neotrioza virginiana* Tuthill, Bull. Brooklyn Ent. Soc. 34:53.

Length to tip of folded wings, 4 mm.

Very closely related to *Trioza obtusa*, but wings are larger, marginal cells larger, Rs straighter. Caudal lobe of male proctiger much more elongate and upcurved, bearing prominent tuft of large setae at apex. Female genital segment similar but more slender in lateral view.

One pair from Maryland and one pair without locality data in the United States National Museum are apparently this species. Described by Miss Patch from Aylmer, Ontario, on "Billberry."

The collection of a male of *Neotrioza virginiana* shows it be identical with *aylmeriae*.

### Genus *Paratrioza*\* Crawford

1909 *Trioza* Sulc (*pro parte*), Acta Soc. Ent. Bohemicae 6:102-108 [*fide* Crawford].

1910 *Paratrioza* Crawford, Pom. Coll. Jour. Ent. 2:228, 229.

1911 *Allotrioza* Crawford (*pro parte*), Pom. Coll. Jour. Ent. 3:423, 442.

1911 *Paratrioza* Crawford, Pom. Coll. Jour. Ent. 3:423, 446 [*designates type*].

1914 *Paratrioza* Crawford, U. S. Nat. Mus., Bull. 85:70.

1917 *Paratrioza* Van Duzee, Cat. Hemip. N. Am. 791.

Head narrower than thorax, scarcely deflexed. Vertex very distinctly margined, anterior margin usually slightly overhanging. Genae usually produced as short, rather broad padlike processes, sometimes conical, sometimes entirely without processes, not spherically swollen. Clypeus visible from anterior view. Antennae slender, variable in length. Thorax moderately arched. Pronotum short, descending anteriorly. Proepisternum strongly produced laterad. Forewings membranous, elongate, acutely angled to somewhat rounded apically, venation triozone. Hind wings much shorter than forewings. Metatibia with basal spur, two inner and one outer apical spines. Metacoxa often with anteriorly projecting process.

Logotype: *Paratrioza cockerelli* (Sulc).

This genus, while exhibiting distinctive characters of its own, seems to represent an intermediate between *Trioza* and *Rhinopsylla*, the latter belonging to the *Carsidarinae* of Crawford. *P. dorsalis* shows a very great similarity to *Rhinopsylla antennata* in all characters except the head which is slightly cleft in *antennata*.

*Kuwayama* Crawford is quite similar to *Paratrioza* but is distinct enough in head characters and type of genitalia to be distinguished. Of the species of the latter, *dubia* n. sp. is most like *Kuwayama*; *dorsalis* is very typically paratriozine except that the genae are utterly devoid of any processes, they are not even swollen as in *Kuwayama*.

\* From *para*, Gr. prep.—near + *trioza*.

Key to the Species of *Paratrioza*

1. Genae produced as small but distinct conical processes. . . . . 2.  
Genae very slightly produced as padlike lobes if at all. . . . . 4.
2. Small species (3 mm. to tip of folded wings); forewings hyaline. . . *cockerelli* p. 585.  
Larger species (3.5 mm. or more to tip of folded wings). . . . . 3.
3. Forewings maculate. . . . . *maculipennis* p. 588.  
Forewings not maculate. . . . . *arbolensis* p. 589.
4. Rs of forewings short, not reaching furcation of media. . . . . *dorsalis* p. 589.  
Rs of forewings longer, extending at least to furcation of media, more or less sinuate. . . . . 5.
5. Ventral valve of female genital segment produced as a large blunt tooth; caudal lobes of male proctiger perpendicular to axial portion. . . . . *lavaterae* p. 590.  
Ventral valve of female genital segment not produced apically; caudal lobes of male proctiger slanting ventrad, touching subgenital plate. . . . . *dubia* p. 591.

*Paratrioza cockerelli*\* (Sulc)

(Figs. 204, 205, 206, 272)

- 1909 *Triozia cockerelli* Sulc, Acta Soc. Ent. Bohemicae. 6:102-108 [*fide* Crawford, 1914b].  
 1910 *Paratrioza ocellata* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1910 *Paratrioza pulchella* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1910 *Paratrioza pulchella flava* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1911 *Paratrioza cockerelli* Crawford, Pom. Coll. Jour. Ent. 3:446, 448.  
 1911 *Paratrioza ocellata* Crawford, Pom. Coll. Jour. Ent. 3:447.  
 1911 *Paratrioza ocellata nigra* Crawford, Pom. Coll. Jour. Ent. 3:447, 448.  
 1911 *Paratrioza ocellata flava* Crawford, Pom. Coll. Jour. Ent. 3:447, 448.  
 1912 *Paratrioza cockerelli* Patch, Me. Agr. Exp. Sta., Bull. 202:231.  
 1913 *Triozia cockerelli* Aulmann, Psy. Cat. 44.  
 1914 *Paratrioza cockerelli* Crawford, U. S. Nat. Mus., Bull. 85:71.  
 1917 *Paratrioza cockerelli* Essig, Jour. Ec. Ent. 10:434-439.  
 1917 *Paratrioza cockerelli* Van Duzee, Cat. Hemip. N. Am. 792.  
 1925 *Paratrioza cockerelli* Ferris, Can. Ent. 57:47-48 [desc. and figs. nymph].  
 1931 *Paratrioza cockerelli* Klyver, Pan-Pac. Ent. 7:142.  
 1931 *Paratrioza cockerelli* Knowlton and Janes, Ann. Ent. Soc. Am. 24:283-290 [life history].  
 1932 *Paratrioza cockerelli* Klyver, Ent. News 43:34.  
 1933 *Paratrioza cockerelli* Richards and Blood, Jour. Agr. Res. 46:189-216.  
 1934 *Paratrioza cockerelli* Knowlton and Thomas, Jour. Ec. Ent. 27:547.  
 1934 *Paratrioza cockerelli* Knowlton, Utah Agr. Exp. Sta., Leaflet 36.  
 1938 *Paratrioza cockerelli* Strickland, Can. Ent. 70:200.  
 1939 *Paratrioza cockerelli* Milliron, Ins. Pest Surv., Bull. 19, 9:564.  
 1939 *Paratrioza cockerelli* Strickland, Can. Ent. 71:213.

Length to tip of folded wings 3 mm.

**COLOR:** General color black typically, with lighter markings varying from white to red. Vertex black except margin and transverse discal area light, dorsum of thorax with light longitudinal stripes. At least posterior portion of pronotum light. Prescutum with a medial longitudinal band and a horseshoe-shaped macula on each side, light. Scutum with a pair of broad medial stripes, a narrow one laterad, lateral margins, light. Posterior margins of abdominal tergites white, first one most prominently so. Extent of pattern somewhat variable, often appearing as dark markings on light ground color. Genal processes and legs usually light. Apices of antennal segments black. Wings hyaline.

\* Named in honor of T. D. A. Cockerell.

**STRUCTURE:** Head of moderate size, narrower than thorax. Margins of vertex raised and abrupt; vertex discally impressed, median suture prominent. Genal processes very small but distinct, divergent, acute. Clypeus visible from anterior or lateral view. Antennae  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Pronotum strongly descending cephalad but not entirely depressed below plane of vertex. Forewings straight, roundly angular, about  $2\frac{1}{2}$  times as long as wide; venation typical triozone, Rs long and sinuate. Hind tibia with two inner apical spines, large basal spur. Caudal spur of metacoxa small, erect, straight, an anterior one of about the same size but flattened.

**GENITALIA:** Male proctiger in lateral view produced caudad as a lobe of variable size and shape, from slender to almost triangular, length through lobe not greater than that of vertical axis, with distinct apical epiphysis. Forceps as long as proctiger in lateral view, slightly curved cephalad apically to acute apices, flattened and somewhat incurved apically; in caudal view straight, narrow. Female genital segment short, about as long as last abdominal sternite; dorsal valve downcurved, black-tipped, acute, anal pore  $\frac{1}{2}$  total length; ventral valve shorter, black and acute apically, slightly produced.

This species is quite variable in color and to a lesser extent in other characters. I have at hand a series of specimens sent to me by Mr. J. R. Eyer of the New Mexico State Agricultural College in which two quite distinct, color "phases" occur. In addition to the typical black individuals, there are numerous specimens so light in color that the general color appears to be yellow. Mr. Eyer reports that these yellow forms occur over the states of New Mexico and Arizona on potatoes in conjunction with the typical ones. He adds that he can find no difference in the nymphs nor in the effect that they have on the potato plants. It is my opinion after examination of the specimens that they do not constitute a species but simply a color variant such as is found in other species of psyllids (*Trioza minuta*, for example). It is possible but improbable that they are merely teneral forms, but as the specimens at hand are mounted on slides or are in alcohol this is difficult to determine. As Knowlton and Janes have pointed out, for 2 or 3 days after emerging, the adults are greenish or amber-colored, subsequently attaining the typical black coloration.

This is the widely known "potato psyllid" or "tomato psyllid" which has developed into one of the most important potato and tomato insects in the western part of North America. The feeding of the nymphs causes the diseased condition known as "psyllid yellows." Numerous solanaceous plants have been recorded as definite hosts supporting the nymphal stages as well as the adult. The adults have been taken on several other plants (see Knowlton, 1933).

The life history has been worked out in detail by Knowlton and Janes (loc. cit.) in Utah. The following brief account is taken from Knowlton (1934):

"The winter is passed in the adult stage, the psyllids finding shelter over winter in the various favorable places which are available. Lack of



excess moisture is important to successful survival. As the early spring host plants, such as matrimony vine, begin to produce their first leaves, the adult potato psyllids congregate upon them, beginning to lay eggs when the leaves are only  $\frac{1}{4}$  to  $\frac{1}{2}$  developed. A part of the first generation usually is matured before the last of the early potato crop has sprouted from the ground. Where breeding plants are not available, adult psyllids will survive for several weeks, feeding upon conifers, grasses, or upon almost any other succulent plant until the potato crop is available. The average number of eggs laid by an individual female is between 300 and 400, most of which hatch under favorable conditions. The eggs of the potato psyllid hatch in from 3 to 9 days in warm weather but may require a longer time if the weather is cool. Upon hatching, the nymph crawls from the egg, creeps down the pedicel supporting the egg, and soon settles down to feeding. Under favorable conditions each nymph passes through 5 molts and instars, or growth periods, requiring from 12 to 19 days for completion. If conditions for growth are unfavorable, the number of molts may vary from four to six; the developmental period may also be longer. No pupal or rest stage occurs in the development of this insect, the winged adult developing directly from the last nymphal stage or instar. Newly emerged adults are usually pale green or light amber in color, darkening to brown and then to blackish-brown during the first 2 or 3 days. The proportion of developing adults is approximately 50 per cent females and 50 per cent males . . .

"Males of the potato psyllid seldom live longer than 1 month; however, 1 female which was under observation lived for more than 6 months, depositing 1,352 eggs over a period of 179 days. Females usually begin laying eggs in from 5 to 12 days after becoming winged; on the average, they continue to lay eggs for the next three weeks, usually depositing from 5 to 50 eggs per day. In northern Utah, 3 to 4 generations develop in 1 season, depending both upon the host sequence available and the length of the season."

For a discussion of "psyllid yellows," the condition caused by feeding of the nymphs, *Psyllid yellows of the Potato*, Richards and Blood (1933), should be consulted.

Numerous specimens are at hand from many localities in Colorado, New Mexico, Arizona, and California. Mr. Oman records the following additional localities from the material in the United States National Museum: Utah, Texas (Winter Garden section of the Rio Grande Valley), Oklahoma (Stillwater), Nebraska (Lincoln, Scottsbluff), South Dakota (Brookings). It has also been recorded from Nevada, Idaho, Montana, Wyoming, Alberta, and Minnesota. As can be judged from these distributional records, it occurs throughout the western portions of North America wherever the winters are neither too cold nor too damp.



*Paratrioza maculipennis*\* (Crawford)

(Fig. 270)

- 1910 *Triozia maculipennis* Crawford, Pom. Coll. Jour. Ent. 2:230, 237.  
1911 *Paratrioza maculipennis* Crawford, Pom. Coll. Jour. Ent. 3:446, 450.  
1913 *Triozia maculipennis* Aulmann, Psy. Cat. 48.  
1914 *Paratrioza maculipennis* Crawford, U. S. Nat. Mus., Bull. 85:73.  
1917 *Paratrioza maculipennis* Van Duzee, Cat. Hemip. N. Am. 792.  
1932 *Paratrioza maculipennis* Klyver, Ent. News 43:35.

Length to tip of folded wings 3.5 mm.

COLOR: General color brown, darkest on abdomen and thoracic dorsum. Antennae black-tipped, apices of segments dark. Thoracic dorsum more or less prominently striped. Wings somewhat milky. Forewings with prominent brown maculae as follows: A narrow irregular one along anal margin from apex to cubital cell; another including most of cubital cell, more or less continuous across wing to furcation of R; an oblique one at tip of Rs; several small ones in clavus.

STRUCTURE: Head large, narrower than thorax. Eyes large. Vertex pubescent, almost flat, two discal foveae, margins prominent. Genal processes well developed but small, parallel to plane of vertex, divergent, less than  $\frac{1}{2}$  as long as vertex. Clypeus visible from front. Antennae about twice as long as width of head, first segment unusually large. Thorax moderately arched, pubescent. Pronotum depressed below plane of vertex. Prescutum broad. Forewings acutely angled,  $2\frac{3}{5}$  times as long as wide; Rs very short, slightly arcuate to costa, media strongly curved, marginal cells somewhat flattened, cubital larger than medial. Hind tibia with two inner apical spines, a prominent tubercle at base, scarcely a spur. Metacoxa with caudal spur of moderate size, anterior process well developed.

GENITALIA: Male proctiger short, with long sloping caudal lobes surrounding forceps, axis through lobes longer than axial portion. Forceps in lateral view broad, curved cephalad to acute apices; in caudal view broad basally, narrowed and arched, apices touching. Female genital segment about as long as preceding sternite; ventral valve produced as a broad truncate tooth; dorsal valve longer than ventral, downcurved, acute, black-tipped.

This beautifully marked species is easily distinguished from other members of the genus by the maculate wings. Specimens are at hand from Anaheim, Sargent, and Strawberry, California. Originally described from California, it has been recorded from numerous localities in that state but from nowhere else. It has been taken on numerous plants, but the host is still unknown.

TYPE, male, San Mateo County, California, Baker, in Crawford Collection.

\* From *macula* -ae, L. f. noun—spot + *pennis*, L.—wing.

*Paratrioza arbolensis*\* Crawford

(Fig. 207, 208, 273)

- 1910 *Paratrioza arbolensis* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1911 *Allotrioza arbolensis* Crawford, Pom. Coll. Jour. Ent. 3:442, 444.  
 1912 *Allotrioza arbolensis* Patch, Me. Agr. Exp. Sta., Bull. 202:231.  
 1914 *Paratrioza arbolensis* Crawford, U. S. Nat. Mus., Bull. 85:72.  
 1917 *Paratrioza arbolensis* Van Duzee, Cat. Hemip. N. Am. 792.

Length to tip of folded wings 4 to 4.5 mm.

COLOR: General color light green to greenish gray. Abdomen darker green to brown. Vertex with anterior band and discal spots typical of genus, dark. Thoracic dorsum with brown longitudinal stripes. Portions of pleurae, ventral side of head and femora brown. Antennae black at tip and at apices of segments. Wings hyaline.

STRUCTURE: Head large, narrower than thorax, not deflexed, flat. Vertex broadly excavate, anterior margin abrupt, medial suture prominent, two very prominent discal sulci. Genal processes definite but very short, projecting forward, strongly divergent. Clypeus large, easily visible from in front. Antennae from  $2\frac{1}{4}$  to  $2\frac{1}{2}$  times as long as width of head. Thorax broad, not strongly arched. Pronotum long, weakly descending cephalad, not depressed below plane of vertex. Forewings large, acutely angled, almost 3 times as long as wide, costal margin arched; Rs moderately long, reaching furcation of media, slightly sinuate, cubital cell very large and long. Legs very large. Hind tibia with two inner apical spines, prominent basal spur. Tarsal segments very long, claws unusually large. Caudal metacoxal processes small, anterior pair larger.

GENITALIA: Male proctiger very short with broad irregularly margined caudal lobes, no epiphysis. Forceps longer than proctiger, flattened; in lateral view broad, apices curved cephalad, beaklike, very sharp-pointed, apical margins black; in caudal view broad at base, narrowed apically. Female genital segment longer than preceding sternite; ventral valve broad, with sharp black median tooth; dorsal valve longer than ventral, narrowed in apical  $\frac{1}{2}$ , dorsal margin almost straight, apex sharp, slender, black, upcurved.

I have a long series of this species, including nymphs, collected on *Shepherdia argentea* Nutt. near Durango, Colorado, July 17, 1938. Other specimens are at hand from various points in Colorado; Green River, Wyoming; and Poplar, Montana.

Host *Shepherdia argentea* Nutt.

TYPE, female, Arboles, Colorado, C. F. Baker, in Crawford Collection.

*Paratrioza dorsalis*† (Crawford)

(Figs. 227, 228, 309)

- 1914 *Kuwayama dorsalis* Crawford, U. S. Nat. Mus., Bull. 85:67.  
 1917 *Kuwayama dorsalis* Van Duzee, Cat. Hemip. N. Am. 791.

\* Adjectival form of *Arboles*—a small town in Colorado near which the original collection was made.

† This appears to be a misspelling of *dorsualis* -e, L. adj.—dorsal; no derivation was given by the author.

Length to tip of folded wings 3.5 to 3.75 mm.

COLOR: Male shining deep brown on head, dorsum of thorax and dorsum of abdomen; venter of abdomen lighter to green, pleurae and venter of thorax brownish to yellow; antennae light, segments black-tipped; margin of first abdominal tergite prominently white; proctiger and forceps white; wings hyaline. Female dark brown only on dorsum of abdomen, remainder of body reddish, legs lighter, with brown reticulate markings on prescutum, scutum, and scutellum, pattern much as on *Paratrioza cockerelli*.

STRUCTURE: Head narrower than thorax, short. Vertex twice as wide as long, somewhat flattened, discal impressions shallow, margins somewhat sharp, sparsely pubescent. Genae scarcely swollen beneath antennae. Clypeus small, visible from front. Antennae slender, slightly over twice as long as width of head. Thorax moderately arched. Pronotum short and depressed below plane of vertex. Prescutum broad, rounding anteriorly. Forewings  $2\frac{1}{2}$  times as long as wide, angulate, costal margin strongly arched; Rs short, almost straight, not reaching fork of media. Legs sturdy. Hind tibia with double basal spur, two inner apical spines. Metacoxa with caudal spur small, erect, with small one anteriorly.

GENITALIA: Male proctiger with broad caudally projecting lobes reaching almost to base of forceps, axis through lobe as long as axial portion, prominent epiphysis apically. Forceps in lateral view almost parallel-margined to near apices then strongly curved cephalad to acute apices; in caudal view broad in basal half then narrower to apices, slightly arched. Female genital segment short; ventral valve shorter than preceding sternite, broad, broadly excavate apically with a median tooth; dorsal valve longer, narrow, overhanging, "hood-shaped," apex acute, black.

Described from one male from Cochise County, Arizona, which was compared with the male type by Mr. Oman, and from four females. One of the females bears the same data as the male and is designated as the ALLOTYPE, Cochise County, Arizona, July 29, 1927, R. H. Beamer. Allotype in Snow Collection, University of Kansas. The three parallotypes bear data as follows: Chiricahua Mountains, Arizona, July 8, 1932, R. H. Beamer (1); Arizona, A. Koebele (2). The latter are in the United States National Museum, the former in the author's collection.

TYPE, male, No. 18080 United States National Museum.

Type examined.

*Paratrioza lavaterae*\* (Van Duzee)

1925 *Kuwayama lavaterae* Van Duzee, Pan-Pac. Ent. 1:22.

1932 *Kuwayama lavaterae* Klyver, Ent. News 43:33.

Length to tip of folded wings 3.25 to 3.75 mm.

COLOR: "Male mostly black; edge of vertex, antennae, frontal cones

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\* Genitive of *Lavatera*—the generic name of the host.

(genae), clypeus, lateral tubercle of pronotum, some marks at base of wings, hind margin of tergal segments one and six and legs, whitish; apical segment of antennae, tips of four preceding and base of first, and the hind femora, except apex, black; anterior and intermediate femora with a brown cloud above; tarsal claws black; wings clear, veins pale, the marginal scarcely darker. Sometimes the mesonotum shows four longitudinal vittae, and there may be one on the prescutum. Female paler, yellowish fulvous to brown, more or less varied with darker; antennae as in male."—Van Duzee.

**STRUCTURE:** Head and thorax sparsely pubescent. Head narrower than thorax. Vertex sharply margined, "plate-like," slightly less than twice as wide as long, discal impressions prominent. Genae produced as small tubercles or pads, not conical. Antennae slender, twice as long as width of head. Thorax strongly arched, prominently punctate. Pronotum strongly descending, short. Prescutum acute anteriorly. Forewings rounding apically, barely angulate, somewhat over  $2\frac{1}{2}$  times as long as wide; Rs long, sinuate, exceeding point of furcation of media, medial cell somewhat larger than cubital. Hind tibia with small basal spur, two inner apical spines. Small anterior metacoxal process.

**GENITALIA:** Male proctiger short, with large caudal lobes, latter broad basally then attenuate and overlapping, longer than axial portion. Forceps in lateral view narrow basally, slightly enlarged, then narrowed to acute apices, slightly curving cephalad; in caudal view fairly stout, parallel-margined, somewhat incurved apically. Female genital segment about as long as 2 preceding segments; ventral valve produced as large, blunt, black tooth; dorsal valve exceeding ventral, slender apically, blunt, black-tipped.

Described from a pair of paratypes. This species was described by Van Duzee from specimens taken on its host plant *Lavatera assurgentiflora* from San Francisco, California. Known only from California.

**TYPE**, male, No. 1592, Museum of the California Academy of Sciences.

*Paratrioza dubia*\* n. sp.

(Figs. 229, 230, 310)

Length to tip of folded wings 3.5 to 3.75 mm.

**COLOR:** General color of head and thorax whitish with orange to brown markings. Vertex light with a narrow band anteriorly and a short transverse band posteriorly, latter often broken. Genae light. Antennae white, apices of segments dark. Thoracic dorsum with somewhat variable longitudinal stripes. Legs light. Dorsum of abdomen chocolate brown, margin of first tergite white. Venter lighter. Genitalia light. Wings smoky.

**STRUCTURE:** Head narrower than thorax. Vertex almost twice as wide as long, margins sharply raised, discally strongly depressed, 2 foveae

\* *dubius* -a -um, L. adj.—doubtful.

near caudal margin, medial suture prominent. Genae slightly swollen, padlike, not conical. Antennae twice as long as width of head. Thorax well arched. Pronotum short, depressed below plane of vertex. Prescutum acute anteriorly. Forewings large, straight, angular,  $1\frac{3}{4}$  times as long as wide; Rs long, sinuate, reaching point of furcation of media, marginal cells about equal. Legs large. Hind tibia with small basal spur, two inner apical spines. Metacoxa with caudal spur of moderate size, small anterior one.

**GENITALIA:** Male proctiger with large slanting caudal lobes, axis through lobes longer than axial portion, lobes enclosing forceps, anus on an oblique epiphysis. Forceps shorter than proctiger; in lateral view slender, very strongly curved cephalad to sharp apices; in caudal view broad basally then slender, slightly arched to apices. Female genital segment short, ventral valve quite flat, rounded and dark apically; dorsal valve narrower, hood-shaped, overhanging, apex black.

**HOLOTYPE**, male, **ALLOTYPE**, female, Patagonia, Arizona, June 24, 1933, R. H. Beamer; four **PARATYPES** same data, two male, three female; **PARATYPES** same data collected by P. W. Oman; one male and two female **PARATYPES** Tubac, Arizona, June 24, 1933, P. W. Oman.

Holotype, allotype, and paratypes in Snow Collection, University of Kansas, paratypes in United States National Museum and author's collection. One male and one female are also at hand from California which are probably this species.

This species resembles both *cockerelli* and *lavaterae* but is distinct, as judged by available specimens.

### Genus *Kuwayama*\*

- 1911 *Epitrioza* Crawford, Pom. Coll. Jour. Ent. 3:423, 452.  
[non] *Epitrioza* Kuwayama, 1910.  
1911 *Kuwayama* Crawford, Pom. Coll. Jour. Ent. 3:503.  
1914 *Kuwayama* Crawford, U. S. Nat. Mus., Bull. 85:65.  
1917 *Kuwayama* Van Duzee, Cat. Hemip. N. Am. 791.

Head narrower than thorax, scarcely deflexed. Vertex not distinctly margined, rounded anteriorly. Genae spherically swollen, prominent. Clypeus visible from anterior view. Antennae slender, moderately long. Thorax not strongly arched. Pronotum short, descending anteriorly. Forewings membranous, elongate, acute to subacute apically, venation triozone. Hind wings slender. Metatibia with basal spur, two inner and one outer apical spines.

**Orthotype:** *Kuwayama medicaginis* (Crawford)

Although this genus is quite similar to *Paratrioza* in many respects it is distinct in the structure of the vertex and genae and in the type of genitalia, both male and female. The type species apparently represents the northernmost member of a natural group, as its congenors are found in Mexico and on various Pacific Islands.

\* The name of Kuwayama, a Japanese entomologist.



The species *dorsalis* Crawford and *lavaterae* Van Duzee have been referred to *Paratrioza* as they show much more relationship to the species of that genus than to *medicaginis*.

*Kuwayama medicaginis*\* (Crawford)

(Figs. 209, 210, 211, 268)

1910 *Paratrioza medicaginis* Crawford, Pom. Coll. Jour. Ent. 2:229.

1911 *Epitrioza medicaginis* Crawford, *ibid.* 3:452.

1914 *Kuwayama medicaginis* Crawford, U. S. Nat. Mus., Bull. 85:66.

1917 *Kuwayama medicaginis* Van Duzee, Cat. Hemip. N. Am. 791.

1932 *Kuwayama medicaginis* Klyver, Ent. News 43:12.

Length to tip of folded wings 3 mm.

**COLOR:** General color sordid white to yellowish. Flavous markings on vertex and thorax, latter forming incomplete longitudinal stripes. Distal tarsal segments and apical  $\frac{2}{3}$  of antennae fuscous. (Crawford records the color as "yellowish green throughout." This is possibly the color of living specimens.)

**STRUCTURE:** Head narrower than thorax. Vertex long, discal impressions very deep; anterior margin overhanging median ocellus, somewhat rounded down. Genae swollen ventrally (rarely with any suggestion of a cone-shaped projection), not touching. Clypeus plainly visible from front. Antennae about  $1\frac{2}{3}$  times as long as width of head. Thorax moderately arched. Pronotum not depressed below plane of vertex. Forewings slender, straight, angulate, almost 3 times as long as broad; Rs long, sinuate. Hind tibia with two inner apical spines, prominent basal spur.

**GENITALIA:** Male proctiger short, curved caudad, caudal margin roundly produced, narrow apical epiphysis. Forceps almost as long as proctiger, broad basally, narrowed to obliquely truncate apices, flattened apically, apical margin heavy, crenate, black; a prominent, acute, antero-lateral projection shorter than principal portion; base heavily pubescent. Female genital segment almost as long as rest of abdomen; apical portion of ventral valve very slender, acute, dark; dorsal valve longer, roundly blunt, black apically.

Numerous specimens are at hand from various localities in Arizona, New Mexico, and Texas. Originally described from Colorado (?) and subsequently recorded from California by Crawford.

Judging from the material at hand it appears that this species occurs in large numbers. Whether alfalfa (*Medicago sativa*) is a true host or not is undetermined.

**TYPE**, male and female on same point, in Crawford Collection, no locality label.

Genus *Neotrioze*† Crawford

1884 *Trioza* Forbes (*pro parte*), 14th Rept. Sta. Ent. Ill. 98.

1911 *Neotrioza* Crawford, Pom. Coll. Jour. Ent. 3:423, 450.

[*non*] *Neotrioza* Kieffer, Ann. Soc. Sci. Brux. 29:32, 1904-05 [*fide* Aulmann].

\* Apparently intended as the genitive of *Medicago*, the supposed host plant.

† From *neos*, Gr.—new + *trioze*—a diminutive form of *trioza*.



- 1911 *Neotriozeila* Crawford, Pom. Coll. Jour. Ent. 3:503.  
 1914 *Neotriozeila* Crawford, U. S. Nat. Mus., Bull. 85:98.  
 1917 *Neotriozeila* Van Duzee, Cat. Hemip. N. Am. 798.  
 1939 *Neotriozeila* Tuthill, Bull. Brooklyn Ent. Soc. 34:51.

Head as broad as or broader than thorax, deflexed. Vertex nearly plane, lateral ocelli borne on raised portions of vertex. Genae produced as elongate, slender, vertical processes, contiguous throughout their length or nearly so. Antennae moderately long. Body small, slender. Thorax very strongly arched. Pronotum short, very strongly descending cephalad. Propisternum strongly produced laterad as flat plate behind eyes. Forewings membranous, long, acutely pointed, venation triozone. Hind wings slender, much shorter than forewings. Metatibia with one or more basal spurs, two or three inner and one outer apical spines.

Orthotype: *Neotriozeila pyrifolii* (Forbes).

### Key to the Species of *Neotriozeila*

- |   |                             |
|---|-----------------------------|
| 1. Genal processes white .....                | 2.                          |
| Genal processes black .....                   | 3.                          |
| 2. Body glabrous, red to brown in color ..... | <i>pyrifolii</i> p. 594.    |
| Body pubescent, very light colored .....      | <i>hirsuta</i> p. 595.      |
| 3. Genal processes longer than vertex .....   | <i>sculptoconus</i> p. 596. |
| Genal processes shorter than vertex .....     | <i>laticeps</i> p. 596.     |

### *Neotriozeila pyrifolii*\* (Forbes)

(Figs. 236, 237, 274)

- 1884 *Trioza pyrifoliae* Forbes, 14th Rept. Sta. Ent. Ill. 98-99.  
 1910 *Trioza immaculata* Crawford, Pom. Coll. Jour. Ent. 2:233.  
 1911 *Neotrioza immaculata* Crawford, Pom. Coll. Jour. Ent. 3:450.  
 1912 *Neotriozeila ottawanensis* Patch, Me. Agr. Exp. Sta., Bull. 202:231.  
 1914 *Neotriozeila immaculata* Crawford, U. S. Nat. Mus., Bull. 85:98.  
 1914 *Trioza proboscidea* Crawford, U. S. Nat. Mus., Bull. 85:99.  
 1917 *Neotriozeila immaculata* Van Duzee, Cat. Hemip. N. Am. 798.  
 1918 *Neotriozeila immaculata* McAtee, Ent. News 29:223.  
 1927 *Trioza pyrifoliae* Frison, Ill. Nat. Hist. Surv., Bull. 16:154 [lectotype designated].  
 1938 *Neotriozeila immaculata* Caldwell, Ohio Biol. Surv., Bull. 34:253.  
 1939 *Neotriozeila pyrifoliae* Tuthill, Bull. Brooklyn Ent. Soc. 34:51.

Length to tip of folded wings 3.5 mm.

COLOR: General color of thorax orange red, head and abdomen brown. Vertex brown to black discally, white to orange on margins. Genal processes white, sometimes brown apically. Antennae black. Pronotum light. Scutum with more or less distinct brown stripes. Legs light to brown.

STRUCTURE: Body slender. Head large, about as broad as thorax. Disc of vertex almost flat. Lateral ocelli very prominently raised, medial suture very prominent. Vertex and pronotum sparsely pubescent. Genal processes slender, attenuate, vertical to retrorse, as long as vertex, or longer. Post-ocular portion of occiput swollen, prominent. Antennae

\* Apparently from *Pyrus*—the pear + genitive of *folium* -ii, L. n. noun—leaf (heretofore used with the incorrect ending -ae).

slender, not quite twice as long as width of head. Thorax strongly arched. Pronotum short, depressed below plane of vertex. Forewings long, slender, blunt, about 3 times as long as wide; Rs very long, sinuate. Hind wings very long, twice as long as abdomen. Legs slender. Hind tibia with three inner apical spines, with two basal spurs.

**GENITALIA:** Male genitalia small. Proctiger pyriform, longer than forceps. Forceps short, broad, spatulate in lateral view; in caudal view slender, straight. Female genital segment almost as long as rest of abdomen; ventral valve slender, acute, dark at apex; dorsal valve longer than ventral, attenuate, not as sharp as ventral.

Originally described from Illinois by Forbes, this species has also been recorded from Iowa (Ames), District of Columbia, Ontario, and Nova Scotia. Specimens are at hand from all the above localities and from Tallulah, Louisiana. The latter series was taken in airplane traps by P. Glick.

**TYPE**, male, in Illinois Natural History Survey Museum.

Male paratype examined.

*Neotriozella hirsuta*\* Tuthill

(Figs. 231, 311)

1939 *Neotriozella hirsuta* Tuthill, Bull. Brooklyn Ent. Soc. 34:52.

Length to tip of folded wings 3 mm.

**COLOR:** General color yellowish white. Eyes, lower edge of margin of vertex, tips of antennal segments and tarsi dark. Prescutum and scutum with yellow stripes. Wings hyaline.

**STRUCTURE:** Head, thoracic dorsum, legs and genital segments with sparse, rather long, silky pubescence. Head large, as wide as thorax. Anterior margin of vertex very abrupt and protruding, disc distinctly concave. Genal processes longer than vertex, closely appressed, rather thick, moderately acute at apex. Antennae slightly over  $1\frac{1}{2}$  times as long as width of head. Thorax strongly arched. Forewings about 3 times as long as wide, veins setaceous. Hind wings long, prominently punctate. Hind tibia with one very large basal spur, two inner apical spines.

**GENITALIA:** Male genitalia moderate in size, covered with very long, fine pubescence. Proctiger greatly produced caudad into enveloping posterior lobes. Forceps as long as proctiger; in lateral view broadest at base, strongly curved caudad to acute black apices; in caudal view evenly incurved, broadest before apex, inner anterior margin produced medially into a blunt, black-margined tooth. Female genital segment rather short, quite suddenly narrowed to black tip; dorsal valve longer than ventral, apices of valves broad and flat.

Known only from the type pair from Arizona.

**TYPE**, male, in Snow Collection, University of Kansas.

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\* *hirsutus* -a -um, L. adj.—hairy.

*Neotriozeila sculptoconus*\* Crawford

- 1914 *Neotriozeila sculptoconus* Crawford, U. S. Nat. Mus., Bull. 85:99.  
 1914 *Trioza frontalis* Crawford, U. S. Nat. Mus., Bull. 85:100.  
 1917 *Neotriozeila sculptoconus* Van Duzee, Cat. Hemip. N. Am. 798.  
 1939 *Neotriozeila sculptoconus* Tuthill, Bull. Brooklyn Ent. Soc. 34:52 [female described].

Length to tip of folded wings 3 mm.

COLOR: Thorax orange to red. Abdomen brownish, lighter beneath. Disc of vertex reddish brown, margin light. Antennae and genal processes black. Pro- and mesotibiae and tarsi dark. Wings hyaline.

STRUCTURE: Head about as wide as thorax. Disc of vertex depressed leaving raised margins except medially in front, pubescent. Genal processes large, acute, contiguous throughout, as long as vertex or a little longer, parallel to plane of vertex. Antennae thick, especially basally, slightly over twice as long as width of head. Thorax slender, very strongly arched. Pronotum depressed, with sparse pubescence. Very short sparse pubescence on remainder of thorax. Forewings long, slender, angulate, 3 times as long as wide; Rs shorter than in *pyrifolii*. Hind wings long, greatly exceeding abdomen. Hind tibia with three inner apical spines, two basal spurs. Metacoxa somewhat produced anteriorly, not spiniform.

GENITALIA: "Male genitalia resemble those of *immaculata*; anal valve relatively longer and produced more into a posterior lobe; forceps broadest subapically, flattened at apex."—Crawford.

Female genitalia similar to *pyrifolii*, almost as long as rest of abdomen, slender; ventral valve narrowed to acute apex; dorsal valve longer than ventral, attenuate, not as sharp, black-tipped.

Known only from three specimens, all from California; two males from Placer and Nevada Counties collected in September by Koebele, one female from Big Bear Lake, July 26, 1932, R. H. Beamer. The above description is from the female allotype.

TYPE, male, No. 18091 United States National Museum.

Type examined.

*Neotriozeila laticeps*† (Crawford)

- 1910 *Trioza laticeps* Crawford, Pom. Coll. Jour. Ent. 2:233.  
 1911 *Neotrioza laticeps* Crawford, Pom. Coll. Jour. Ent. 3:451.  
 1914 *Neotriozeila laticeps* Crawford, U. S. Nat. Mus., Bull. 85:100.  
 1917 *Neotriozeila laticeps* Van Duzee, Cat. Hemip. N. Am. 798.  
 1932 *Neotriozeila laticeps* Klyver, Ent. News 43:38.  
 1939 *Neotriozeila laticeps* Tuthill, Bull. Brooklyn Ent. Soc. 34:53.

Crawford's description of this species is as follows:

"Length of body 1.6 mm.; length of forewing 2.7; width of head 0.62.

General color dark brown, thorax lighter; head and genal cones black.

"Head strongly deflexed, distinctly broader than thorax, slightly

\* From *sculptus*, L. (p. part. of *sculpo*—to carve, grave) + *conus* -i, L. m. noun—cone.

† From *latus* -a -um, L. adj.—broad + *ceps* a combining form of *caput*, L. n. noun—head.

punctate; vertex rather sharply defined on margin, scarcely impressed discally, slightly emarginate over front ocellus; genal cones not longer than vertex, acute, more abruptly converging to apex than in *immaculata*, vertical or retrorse, slightly pubescent. Antennae very slender.

"Thorax arched, narrow, punctate, slightly pubescent. Wings hyaline, narrower than in *immaculata*, relatively longer usually, subacute at apex.

"*Genitalia*: Female genital segment almost as long as rest of abdomen, very acute at apex; dorsal valve longer and larger than ventral, very acute.

"Described from one female collected by G. R. Pilate in Louisiana. This is very close in many respects to *immaculata*."

TYPE, female, No. 18092 United States National Museum.

Type examined.

### Genus *Metatrioza*\* Tuthill

1939 *Metatrioza* Tuthill, Bull. Brooklyn Ent. Soc. 34:53.

Head large, at least as broad as thorax. Vertex with sharp anterior and posterior margins, strongly concave between eyes, medial suture prominent. Genal processes not contiguous. Clypeus very small. Dorsum of thorax rather broad and flat, pronotum not depressed below head. Forewings with typical triozone venation, except cubital cell which is unusually large. Metatibia with large basal spur, one outer and two inner apical spines.

Orthotype: *Metatrioza pubescens* Tuthill.

### *Metatrioza pubescens*† Tuthill

(Figs. 232, 233, 238, 312)

1939 *Metatrioza pubescens* Tuthill, Bull. Brooklyn Ent. Soc. 34:53.

Length to tip of folded wings 4 mm.

COLOR: General color reddish brown. Genal processes, pronotum and posterior portion of vertex yellow. Venter and antennae dark. Forewings hyaline, hind wings more or less white.

STRUCTURE: Body finely punctate, clothed with short, fine pubescence, including veins of forewings, pubescence most prominent on genital segments, legs, and antennae. Head very large, as wide as thorax, 3 times as wide as long in dorsal view, strongly deflexed. Vertex as long as wide, sharply margined both anteriorly and posteriorly, deeply excavate, medial suture prominent. Anterior ocellus large, beneath overhanging margin of vertex. Frons visible as a distinct sclerite, not covered by genal processes, latter not contiguous, short,  $\frac{1}{2}$  as long as disc of vertex, slightly divergent, rather blunt. Clypeus very small, entirely invisible from front.

\* *meta*, Gr. prep—in company with + *trioza*.

† *pubescens*, L. (pres. part. of *pubescere*)—pubescent, having hair.

Antennae slightly over twice as long as width of head. Pronotum not depressed below level of head, episterna strongly produced. Prescutum not very strongly arched, about  $1\frac{2}{3}$  times as wide as long. Forewings acute at apex, 3 times as long as wide; veins prominently pubescent, marginal cells large, cubital larger than medial, Rs very long, curved. Venation of hind wings unusually prominent. Hind tibia with very prominent basal spur, two inner and one outer apical spines.

**GENITALIA:** Male genitalia of moderate size. Proctiger longer than forceps, almost equilaterally triangular in outline, broadest near base, truncate at apex. Forceps simple; in caudal view somewhat broader at base, slightly bowed, apices blunt, with very small medial black tooth. Female genital segment quite large, about  $\frac{3}{4}$  as long as rest of abdomen; dorsal valve longer than ventral.

Known only from the type series from the Baboquivari Mountains, Arizona. Host plant unknown.

TYPE, male, in Snow Collection, University of Kansas.

### Genus *Leuronota*\* Crawford

- 1910 *Trioza* Crawford (*pro parte*), Pom. Coll. Jour. Ent. 2:230, 349.  
 1911 *Allotrioza* Crawford (*pro parte*), Pom. Coll. Jour. Ent. 3:423, 442.  
 1914 *Leuronota* Crawford, U. S. Nat. Mus., Bull. 85:67.  
 1917 *Leuronota* Van Duzee, Cat. Hemip. N. Am. 791.  
 1920 *Leuronota* Crawford, Proc. Haw. Ent. Soc. 4:374.  
 1928 *Leuronota* Ferris, Can. Ent. 60:240.

Head narrower than thorax, scarcely or not at all deflexed. Genae produced as conical processes, porrect. Antennae slender, long. Eyes hemispherical. Thorax scarcely arched. Pronotum flat, long, on same plane as vertex and prescutum, produced cephalad medially as blunt epiphysis, very narrow. Proepisterna very large, visible in dorsal view as prominent quadrate lateral processes. Prescutum flat with a small median anterior epiphysis. Mesopleurites strongly developed. Forewings long, slender, angulate, venation triozone. Legs long. Metatibia with basal spur, two or three inner, one outer apical spines.

Orthotype: *Leuronota maculata* (Crawford).

A total of nine species has been referred to this genus, only two of which occur north of Mexico. Three of the nine were originally described in *Cerotrioza* by Crawford and subsequently (1920) placed in *Leuronota* by him. From his descriptions of these latter species it seems unlikely that they are congeners of *maculata*, but as I have seen no specimens of any of the three, no other disposition can be made at this time.

The nymphs apparently produce galls or semi-galls on their host plants.

\* From *leuros*, Gr. Adj.—flat + *noton* -i, Gr. m. noun—back.



Key to the Species of *Leuronota*

1. Antennae  $2\frac{1}{2}$  times as long as width of head; genal processes somewhat descending.....*maculata* p. 599.  
 Antennae 3 times as long as width of head; genal processes extending forward on same plane as vertex.....*longipennis* p. 599.

*Leuronota maculata*\* (Crawford)

(Figs. 239, 240, 241, 275)

- 1910 *Trioza maculata* Crawford, Pom. Coll. Jour. Ent. 2:230, 349.  
 1911 *Allotrioza maculata* Crawford, Pom. Coll. Jour. Ent. 3:444, 446.  
 1913 *Trioza maculata* Aulmann, Psy. Cat. 48.  
 1914 *Leuronota maculata* Crawford, U. S. Nat. Mus., Bull. 85:68.  
 1917 *Leuronota maculata* Van Duzee, Cat. Hemip. N. Am. 791.  
 1928 *Leuronota maculata* Ferris, Can. Ent. 60:240.  
 1932 *Leuronota maculata* Klyver, Ent. News 43:34.

Length to tip of folded wings 3.25 to 4 mm.

COLOR: General color dirty white to brown, abdomen darker. Forewings with numerous small brown dots forming maculae as figured, amount of maculation quite variable.

STRUCTURE: Entire body more or less pubescent. Head narrower than thorax, not deflexed. Vertex almost plane, discal foveae more or less prominent. Genal processes short, blunt, divergent apically, about  $\frac{1}{2}$  as long as vertex, somewhat deflexed from plane of vertex. Antennae slender,  $2\frac{1}{2}$  times as long as width of head. Clypeus large, visible in cephalic view. Thorax scarcely arched. Pronotum flat, above plane of vertex, acute epiphysis medially on anterior margin fitting into excavate posterior margin of vertex. Prescutum broad, lateral margins long. Forewings slender, 3 times as long as wide or slightly over, roundly angulate; Rs straight then arched to costal margin, cubital cell larger than medial. Hind tibia with three inner apical spines.

GENITALIA: Male proctiger of medium length, rather stout, straight, anal pore opening antero-dorsally. Forceps very short; in lateral view broad, produced dorso-cephalically as long, acute lobes; in dorso-caudal view broad, flattened, arched to black-tipped apices. Female genital segment about  $\frac{1}{2}$  as long as rest of abdomen, thick dorso-ventrally; dorsal valve somewhat hood-shaped, exceeding ventral, ventral margin of latter straight for about  $\frac{1}{2}$  its length then sharply upturned to acute apex.

Ferris gives *Celtis iguanea* as a definite host, having taken both nymphs and adults on this plant. Many specimens are at hand from Arizona taken on *Celtis pallidis* Torr.

TYPE, female, Arizona 2315, in Crawford Collection.

*Leuronota longipennis*† Crawford

- 1914 *Leuronota longipennis* Crawford, U. S. Nat. Mus., Bull. 85:68, 69.  
 1917 *Leuronota longipennis* Van Duzee, Cat. Hemip. N. Am. 791.

\* *maculatus*, L. (p. part. of *maculare*)—spotted.

† From *longus* -a -um, L. adj.—long + *pennis*, L. f. noun—wing.



Crawford's description of this species is as follows:

"Length of body 2.8 mm.; length of forewing 3.1; width of head 0.68.

"General color brown; genal cones, anterior margin of pronotum, part of sternum, legs, antennae except terminal segment very light brown; antennal segments tipped with brown.

"Head small, flattened, not deflexed, not as broad as thorax; vertex flat, with a broad, shallow depression on each side of median line, smooth; genal cones about  $\frac{2}{3}$  as long as vertex, extending forward in same plane with vertex, divergent, subacute at apex, slightly pubescent. Clypeus far back, with a conspicuous cavity in front of it between genae. Antennae more than 3 times as long as width of head, slender.

"Thorax not arched, flat, narrow; pronotum moderately long, anterior epiphysis smaller than in two preceding species [*maculata* and *crawfordi*]. Legs slender. Wings nearly 4 times as long as broad, very narrow, narrowly rounded at apex, apical third brown, basal  $\frac{2}{3}$  transparent, membrane coarsely punctate; first marginal cell larger than second; radial sector long.

"GENITALIA: Male genital segment small; anal valve much longer than forceps, fusiform, narrow at apex, with processes; forceps small, short, slender, acute at tip, strongly arcuate; pubescence short.

"Described from 1 male from Palm Beach, Florida (H. G. Dyar), no data.

"TYPE, Cat. No. 18081, United States National Museum.

"This species bears some resemblance to members of the European genus *Floria*."

Type examined.

### Genus *Ceropsylla*\* Riley

1885 *Ceropsylla* Riley, Proc. Biol. Soc. Wash. 2:76.

1910 *Ceropsylla* Crawford, Pom. Coll. Jour. Ent. 2:229.

1911 *Ceropsylla* Crawford, Pom. Coll. Jour. Ent. 3:423.

1911 *Triozoida* Crawford (*pro parte*), Pom. Coll. Jour. Ent. 3:493.

1913 *Ceropsylla* Aulmann, Psy. Cat. 59.

1914 *Ceropsylla* Crawford, U. S. Nat. Mus., Bull. 85:100.

1917 *Ceropsylla* Van Duzee, Cat. Hemip. N. Am. 798.

Head narrower than thorax. Vertex smooth, somewhat rounded, portion bearing lateral ocelli very strongly raised, next eyes rounding evenly into genae, medially overhanging median ocellus. Genae produced as short, blunt processes extending somewhat forward, a second pair of small rounded processes next eyes, below antennal insertions. Antennae slender, long, arising close together and far down on genae, largely on genal processes. Eyes hemispherical, very large. Thorax strongly arched. Pronotum very short, vertical, depressed below vertex and prescutum. Proepisternum produced laterad, platelike. Prescutum as long as wide, very strongly arched. Mesopleurites strongly developed, episternum very large, swollen. Forewings large, membranous, angulate apically,

\* From *ceros* -ou, Gr. m. noun—wax + *psylla*.

basal vein ( $R + M + Cu$ ) very long, parallel to costa, cubitus arising separately, radius and media with a short petiole,  $R$  very short,  $R_1$  long,  $Rs$  very short, no pterostigma. Hind wings much shorter than forewings. Metatibia with basal spur, one outer and two inner apical spines.

Haplotype: *Ceropsylla sideroxyli* Riley.

This genus is most peculiar in the characters of the head and venation of the wings. The position of the antennal insertion is unique, in the North American Psyllidae at least. The extremely long basal vein of the forewings is very distinctive as is the very short base of  $R$  and short  $Rs$ . Cubitus arises separately from the basal vein leaving radius and media with a short common base as described by Riley, not cubitus and media on a common petiole as Crawford states. This character I do not consider to be of the importance that Crawford attached to it.

Crawford synonymized his *Triozoida* with *Ceropsylla*; from his descriptions and figures of *johnsonii* it would seem to be congeneric with *sideroxyli* except for the disparity in wing venation. As no specimens of *johnsonii* have been seen, it is left in this genus for the present. The other species placed here by Crawford, *californica*, is referred back to *Triozoa*.

### *Ceropsylla sideroxyli*\* Riley

(Figs. 242, 243)

- 1885 *Ceropsylla sideroxyli* Riley, Proc. Biol. Soc. Wash. 2:76.  
 1910 *Ceropsylla sideroxyli* Crawford, Pom. Coll. Jour. Ent. 2:229.  
 1911 *Ceropsylla sideroxyli* Crawford, Pom. Coll. Jour. Ent. 3:423.  
 1913 *Ceropsylla sideroxyli* Aulmann, Psy. Cat. 59.  
 1914 *Ceropsylla sideroxyli* Crawford, U. S. Nat. Mus., Bull. 85:101.  
 1917 *Ceropsylla sideroxyli* Van Duzee, Cat. Hemip. N. Am. 798.  
 1923 *Ceropsylla sideroxyli* Ferris, Can. Ent. 55:254 [nymph].  
 1928 *Ceropsylla sideroxyli* Ferris, Can. Ent. 60:245.

Length to tip of folded wings 4 mm.

COLOR: General color green to yellow. Front of head, between antennae, including genal processes, anterior  $\frac{2}{3}$  of prescutum and two broad stripes on scutum, dark brown. Antennae dark apically. Wings hyaline.

STRUCTURE: Dorsum with short sparse pubescence. Head small, narrower than thorax. Vertex very small, rounded downward both posteriorly and anteriorly, except over median ocellus. Eyes very large. Lateral ocelli on raised prominences, far forward, almost midway of eyes. Genae separated medially to above bases of antennae, below antennae genae produced into short, bluntly rounded processes. Antennae  $1\frac{1}{2}$  times as long as width of head, arising far down on genae, and close together. Thorax strongly arched. Pronotum depressed below plane of vertex. Prescutum large, rounded anteriorly, as long as wide. Mesopleurites very large, swollen. Forewings long, slender, acutely angled, 3 times as long as wide; basal vein ( $R + M + Cu$ ) very long;  $R$  and  $M$  with a short common stem;  $Rs$  very short, straight; cubital cell larger than medial. Hind tibia with small basal spur, one outer and two inner apical

\* Genitive of *Sideroxylum*—the generic name of the host.

spines. Metacoxa with posterior spur of moderate size, anteriorly somewhat produced but not spiniform.

**GENITALIA:** Male proctiger produced caudad as a broad rounded lobe. Forceps shorter than proctiger; in lateral view slender, slightly curved cephalad, a short, slender, curved process near base on anterior margin; in caudal view slender to spatulate apices. Female genital segment longer than preceding sternite; ventral valve very broad, slightly sinuate to a medial, broad, truncate tooth; dorsal valve exceeding ventral, narrower, blunt.

Described from specimens from Lake Worth, Florida (E. A. Schwarz) in the United States National Museum. According to Riley this species forms galls on the leaves of "*Sideroxylon masticodendron*," evidently the mastic, the name of which as given by Sargent is *Sideroxylum foetidissimum* Jacq.

Ferris describes and figures the nymph which is apparently even more strikingly distinct than the adult. He also records it from Mexico, the only record of its occurrence outside of Florida.

TYPE, No. 695 United States National Museum (6 cotypes).

Types examined.

#### Genus *Hemitrioza*\* Crawford

1914 *Hemitrioza* Crawford, U. S. Nat. Mus., Bull. 85:104.

1917 *Hemitrioza* Van Duzee, Cat. Hemip. N. Am. 798.

Head much narrower than thorax, deflexed. Vertex without abrupt margins. Genal processes short, strongly divergent. Clypeus small. Antennae moderately long. Eyes very small, hemispherical. Thorax broad, moderately arched. Pronotum short, depressed, strongly descending cephalad. Forewings short, membranous, bluntly angulate, usually media and cubitus with a short common basal petiole, sometimes none (varying on wings of individual), basal vein long. Hind wings much smaller than forewings. Metatibia without basal armature, one outer and three or four inner apical spines. Metatarsus without claws on basal segment.

Orthotype: *Hemitrioza sonchi* Crawford.

As Crawford notes, this genus while distinctly triozone in general, shows some psylline characteristics.

Klyver's species *washingtonia* appears from his figures to be congeneric with *sonchi* although it differs from the latter markedly in some respects, notably the very short antennae, the longer and less angulate wings, and the venation.

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\* From *hemi*, Gr. prefix—half + *trioza*.

Key to the Species of *Hemitrioza*

1. Costal margin of forewings strongly arched, Rs arched to costa, short, not reaching furcation of media; general color red, antennae, tibiae and tarsi white, forewings maculate.....**sonchi** p. 603.  
Costal margin of forewings not strongly arched, Rs long, straight, extending beyond furcation of media; general color brown, forewings immaculate  
**washingtonia** p. 604.

*Hemitrioza sonchi*\* Crawford

(Figs. 244, 245)

- 1884 *Trioza sonchi* Riley, Proc. A.A.A.S. 32:319 [*nomen nudum*].  
1913 *Trioza sonchi* Aulmann, Psy. Cat. 55 [*nomen nudum*].  
1914 *Hemitrioza sonchi* Crawford, U. S. Nat. Mus., Bull. 85:104.  
1917 *Hemitrioza sonchi* Van Duzee, Cat. Hemip. N. Am. 799.

Length to tip of folded wings 2.5 to 3 mm.

COLOR: General color red. Tibiae, tarsi, and antennae white, latter black-tipped. Wings hyaline except a broad band across middle and three or four spots on posterior margin, brown.

**STRUCTURE:** Head small. Vertex with deep discal foveae, rounding down in front, deeply emarginate. Eyes very small. Genal processes stout, strongly divergent, acute, about  $\frac{1}{2}$  as long as vertex. Antennae rather short, stout, slightly over twice as long as width of head, segment III thicker than distal segments. Thorax proportionately very broad, weakly arched. Pronotum almost as wide as head, above plane of vertex. Forewings short, slightly over twice as long as wide, narrowly rounded apically, membrane thickly set with minute setae. Costal margin strongly arched; media and cubitus with a short common petiole, length somewhat variable; Rs short, arched to costa. Hind wings very small, thickly set with minute setae. Hind tibia with three inner apical spines.

GENITALIA: Male genitalia described by Crawford as follows: "Forceps about  $\frac{1}{2}$  as long as anal valve, [proctiger] thick at base and converging to apex to a sharp toothlike point, arcuate somewhat; anal valve rather large, elliptical (from side view), broadest at middle; forceps and anal valve quite densely pubescent." Female genital segment longer than preceding sternite, ventral valve rounded apically, dorsal valve longer, blunt.

This species is represented in the material at hand by two females from the District of Columbia. It was described from Virginia, District of Columbia, and Atlanta, Georgia. It is recorded from *Sonchus arvensis* (Riley's specimens). Crawford mentions the nymph but gives no host plant data.

TYPE, female, No. 18094 United States National Museum.

Type examined.

\* Genitive of *Sonchus*—the generic name of the supposed host.

*Hemitrioza washingtonia*\* Klyver

(Figs. 246, 247)

1932 *Hemitrioza washingtonia* Klyver, Pan-Pac. Ent. 8:14-15.

"Length of body on slide, 2.0 mm.; length of forewing, 1.8 mm.; width of head, .6 mm. General color of entire body uniform medium brown. Eyes dark brown. Genae lighter than the general color. Tip of antenna black. Wings uniform brown (including veins), semi-opaque, shiny; hind wings iridescent. Agreeing fairly well with the characters of the genus as defined by Crawford except that the head is not much narrower than the thorax, the eyes are not proportionately very small, and the hind tibia has 4 instead of 3, apical spines or teeth on the inner aspect.

"Head strongly deflexed. Antenna ten-segmented with the third segment nearly as long as segments 4, 5, 6, and 7 combined; antennal sensoria obscure; antenna scarcely as long as width of head.

"Thorax moderately arched; without pubescence. Posterior tibia with 1 large black tooth and a comb of setae on the outer aspect and with 4 black teeth, 2 of them large and 2 distinctly smaller, on the inner aspect. Forewing semi-opaque and punctate throughout with a suggestion of alar radulae in the 2 marginal cells and between  $Cu_1$  and  $M_3 + 4$ ; . . . with irregular venation, *in the same individual* . . . Posterior wing distinctly brown, with the venation . . ., developed for the most part as little more than streaks of brown along which the punctations that beset the entire wing membrane are arranged in more or less definite but irregular rows.

"Abdomen with the tergites and sternites uniformly and equally chitinized; with small pleurites at the lateral extremities of tergites 4, 5, 6, and 7. Male genitalia relatively small; the proctiger oval in lateral view, with sparse pubescence; the clasper simple in structure, with the distal end directed anteriorly."—Klyver.

This species was described from one male from Toppenish, Washington.

TYPE in Klyver's collection.

Genus *Levidea*† Tuthill1938 *Levidea* Tuthill, Ent. News 49:245.

Head small, much narrower than thorax, deflexed. Vertex perpendicular, rounded, smooth, median suture lacking or at least apparent only above front ocellus, no discal impressions. Genae somewhat swollen below antennae, almost touching. Clypeus large and globose, visible from front. Antennae slender, of moderate length, longer than width of head. Eyes small, hemispherical. Thorax moderately arched. Pronotum nearly vertical, broad. Proepisternum produced laterad, plate-like around posterior of eye. Forewings long, pointed apically, somewhat coriaceous,

\* An adjectival form of Washington.

† From *levis* -e, L. adj.—smooth + *idea* -ae, L. f. noun—form.



radius, media and cubitus arising from basal vein ( $R + M + Cu$ ) at same point, no pterostigma. Metatibia with basal spur, one outer and two inner apical spines. Metatarsus without claws on basal segment.

Orthotype: *Levidea lineata* Tuthill.

This genus is included in the *Triozinae* chiefly on the venation of the forewings. The head is quite unlike any other members of this subfamily. It perhaps is more closely related to some other genera with which I am unfamiliar.

*Levidea lineata*\* Tuthill

(Figs. 234, 235, 248, 313)

1938 *Levidea lineata* Tuthill, Ent. News 49:245.

Length to tip of folded wings, 3 to 3.5 mm.

COLOR: General body color, including legs, stramineous. Vertex and genae light, antennae darker. Eyes dark. Two brown lines extending across prescutum, sometimes incomplete, continuing on scutum as a diverging pair of lines. Membrane of forewings with small brown spots, very thick at anal margin to sparse on costal margin, the veins unspotted except at marginal cells, thus giving general appearance of stripes.

STRUCTURE: Head very small, strongly deflexed. Vertex slightly swollen in appearance, perfectly smooth except for two very small foveae near occipital margin and remnant of medial suture above front ocellus. Genae slightly swollen. Clypeus very large, visible from front or side. Antennae twice as long as width of head. Thorax moderately arched. Pronotum developed out and around the occiput. Forewings slightly more than twice as long as wide, without pterostigma or cubital petiole, marginal cells about equal. Metatibia with stout basal spur, one outer, two inner apical spines.

GENITALIA: Male genitalia large, proctiger triangular in outline, broad at base, slightly longer than forceps which are simple, tapering from base to acute apices, quite strongly arched, apices touching, pubescent on posterior margins. Female genital segment large with rather dense, silky pubescence; dorsal valve very large, hood-shaped; ventral valve smaller, sharply pointed.

Known only from the type series from Arizona. The probable host is *Parthenium incanum*, "wild rubber."

HOLOTYPE, female, No. 55185 United States National Museum.

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\* Adjectival form of *linea*, L.—line.



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## EXPLANATION OF PLATES

## LIST OF ABBREVIATIONS

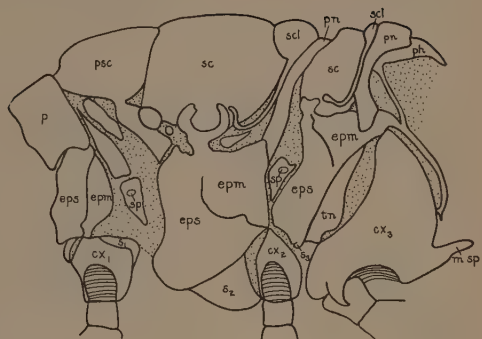
a—anus	ph—phragma
ae—aedeagus	pn—postnotum
ant—antenna	psc—prescutum
cl—clypeus	ptg—proctiger
cx—coxa	s—sternum
dv—dorsal valve of female genital segment	sc—scutum
e—eye	scl—scutellum
epl—epipleurite	sgp—subgenital plate
epm—epimeron	sp—spiracle
eps—episternum	st—sternite
f—forceps	t—tergite
fr—frons	tn—trochantin
gp—genal process	v—vertex
lab—labium	vv—ventral valve of female geni- tal segment
m sp—metacoxal spur	w—wing
o—ocellus	wp—wing process
p—pronotum	

## PLATE I

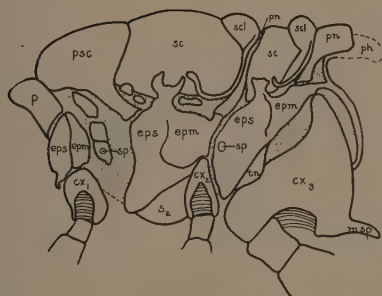
- FIG. 1. *Psylla alni*—frontal aspect of head.  
2. *Psylla alni*—lateral aspect of thorax (Crawf.).  
3. *Trioza albifrons*—lateral aspect of thorax (Crawf.).  
4. *Psylla pyricola*—lateral aspect of abdomen of female (Crawf.).  
5. *Psylla pyricola*—lateral aspect of abdomen of male (Crawf.).  
6. *Arytaina robusta*—lateral aspect of head and thorax (Crawf.).



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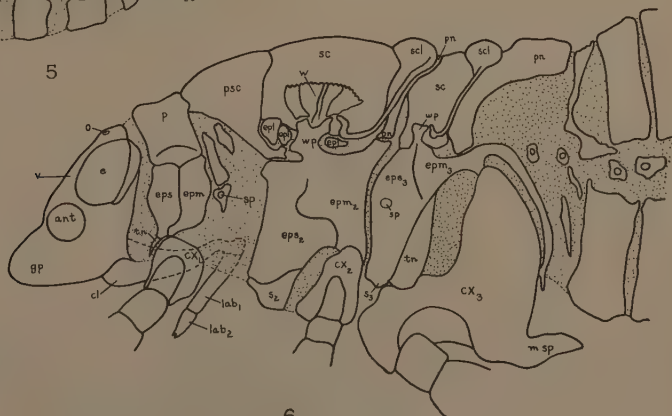
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## PLATE II

- FIG. 7. *Psylla alni*—female cauda (Crawf.).  
8. *Psylla alni*—male cauda (Crawf.).  
9. *Psylla caudata*—female cauda (Crawf.).  
10. *Psylla caudata*—male cauda.  
11. *Psylla galeaformis*—male cauda.  
12. *Psylla galeaformis*—female cauda.  
13. *Psylla floccosa*—female cauda (Crawf. mod.).  
14. *Psylla floccosa*—male cauda (Crawf. mod.).  
15. *Psylla trimaculata*—female cauda (Crawf.).  
16. *Psylla trimaculata*—male cauda (Crawf.).



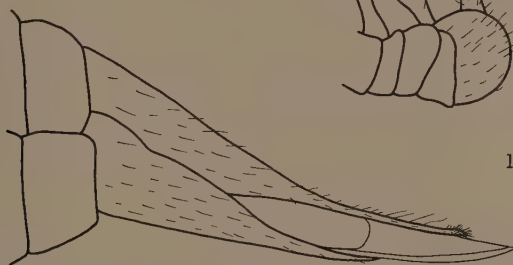
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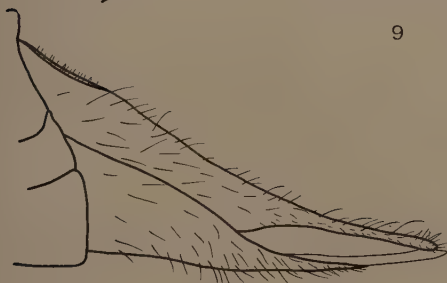
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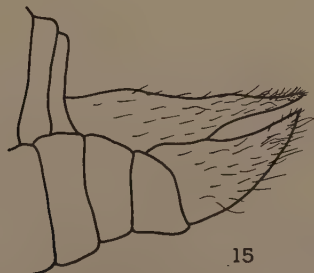
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## PLATE III

- FIG. 17. *Psylla maculata*—female cauda (Crawf.).  
18. *Psylla albagenta*—female cauda (Cald.).  
19. *Psylla albagenta*—male cauda (Cald.).  
20. *Psylla carpinicola*—male cauda (Crawf.).  
21. *Psylla carpinicola*—female cauda (Crawf.).  
22. *Psylla dilonchi*—female cauda (Cald. mod.).  
23. *Psylla dilonchi*—male cauda (Cald. mod.).  
24. *Psylla striata*—female cauda.  
25. *Psylla striata*—male cauda.  
26. *Psylla minuta*—female cauda (Crawf. mod.).  
27. *Psylla brevistigmata*—female cauda.  
28. *Psylla brevistigmata*—male cauda.  
29. *Psylla difficilis*—female cauda.  
30. *Psylla difficilis*—male cauda.  
31. *Psylla hartigii*—male cauda.  
32. *Psylla hartigii*—female cauda.  
33. *Psylla tuthilli*—female cauda (Cald.).



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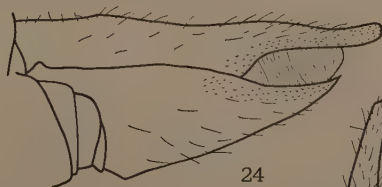
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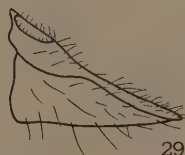
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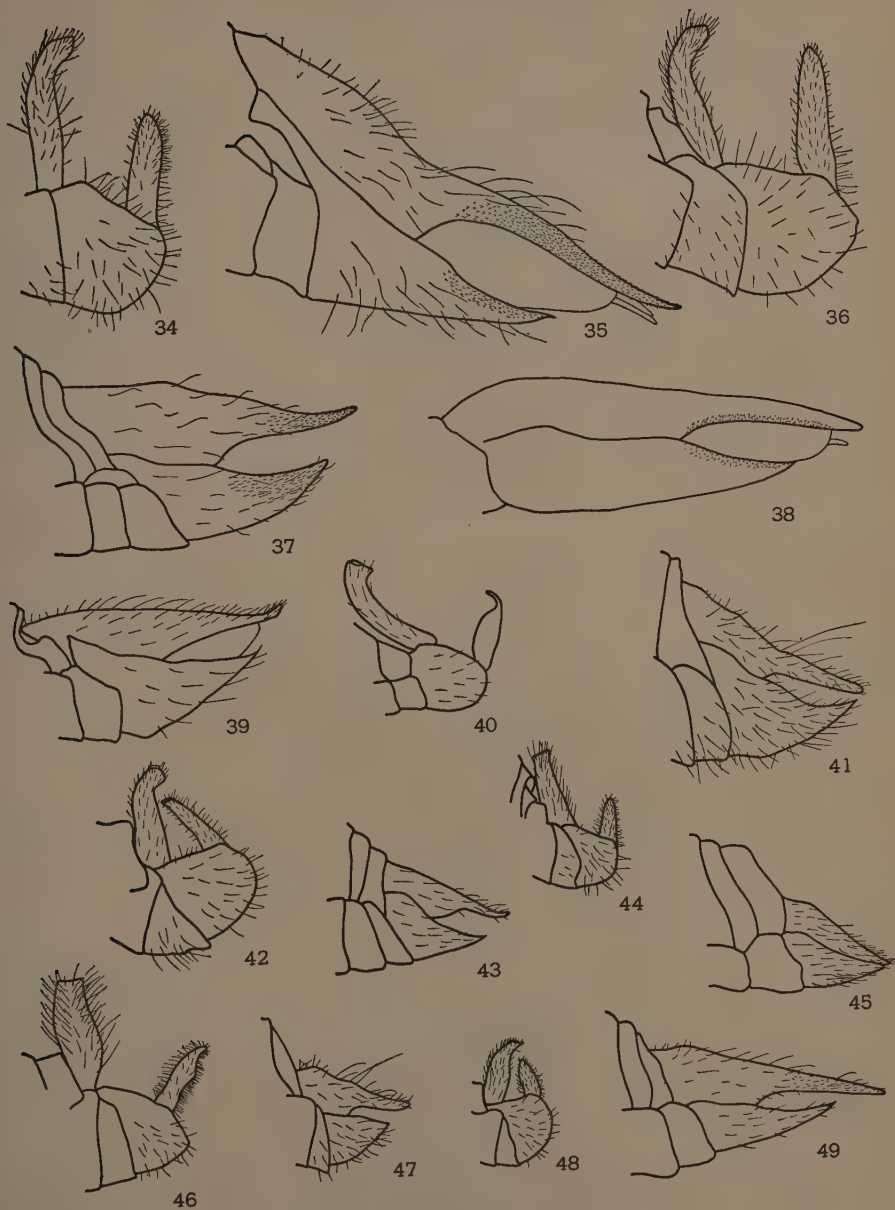
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## PLATE IV

- FIG. 34. *Psylla stricklandi*—male cauda.  
35. *Psylla stricklandi*—female cauda.  
36. *Psylla magnicauda*—male cauda.  
37. *Psylla magnicauda*—female cauda (Crawf.).  
38. *Psylla buxi*—female cauda (Cald.).  
39. *Psylla breviata*—female cauda.  
40. *Psylla breviata*—male cauda (Crawf.).  
41. *Psylla mali*—female cauda.  
42. *Psylla mali*—male cauda.  
43. *Psylla alba*—female cauda (Crawf.).  
44. *Psylla alba*—male cauda.  
45. *Psylla ribesiae*—female cauda (Crawf.).  
46. *Psylla ribesiae*—male cauda.  
47. *Psylla pyricola*—female cauda.  
48. *Psylla pyricola*—male cauda.  
49. *Psylla americana*—female cauda (Crawf.).



## PLATE V

- FIG. 50. *Psylla phoradendri*—female cauda.  
51. *Psylla phoradendri*—male cauda.  
52. *Psylla maculata*—male cauda, lateral aspect.  
52a. *Psylla maculata*—caudal aspect of forceps.  
53. *Psylla nana*—female cauda.  
54. *Psylla nana*—male cauda.  
55. *Psylla insignita*—male cauda.  
56. *Psylla insignita*—female cauda.  
57. *Psylla magna*—female cauda.  
58. *Psylla magna*—male cauda.  
59. *Psylla omani*—female cauda.  
60. *Psylla omani*—male cauda.  
61. *Psylla hirsuta*—female cauda.  
62. *Psylla hirsuta*—male cauda.  
63. *Psylla media*—female cauda.  
64. *Psylla media*—male cauda.  
65. *Psylla alaskensis*—female cauda.  
66. *Psylla alaskensis*—male cauda.  
67. *Psylla bulbosa*—female cauda.  
68. *Psylla bulbosa*—male cauda.



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52a



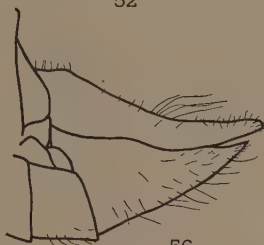
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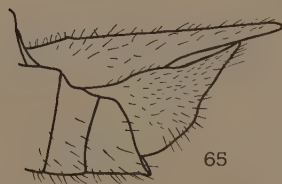
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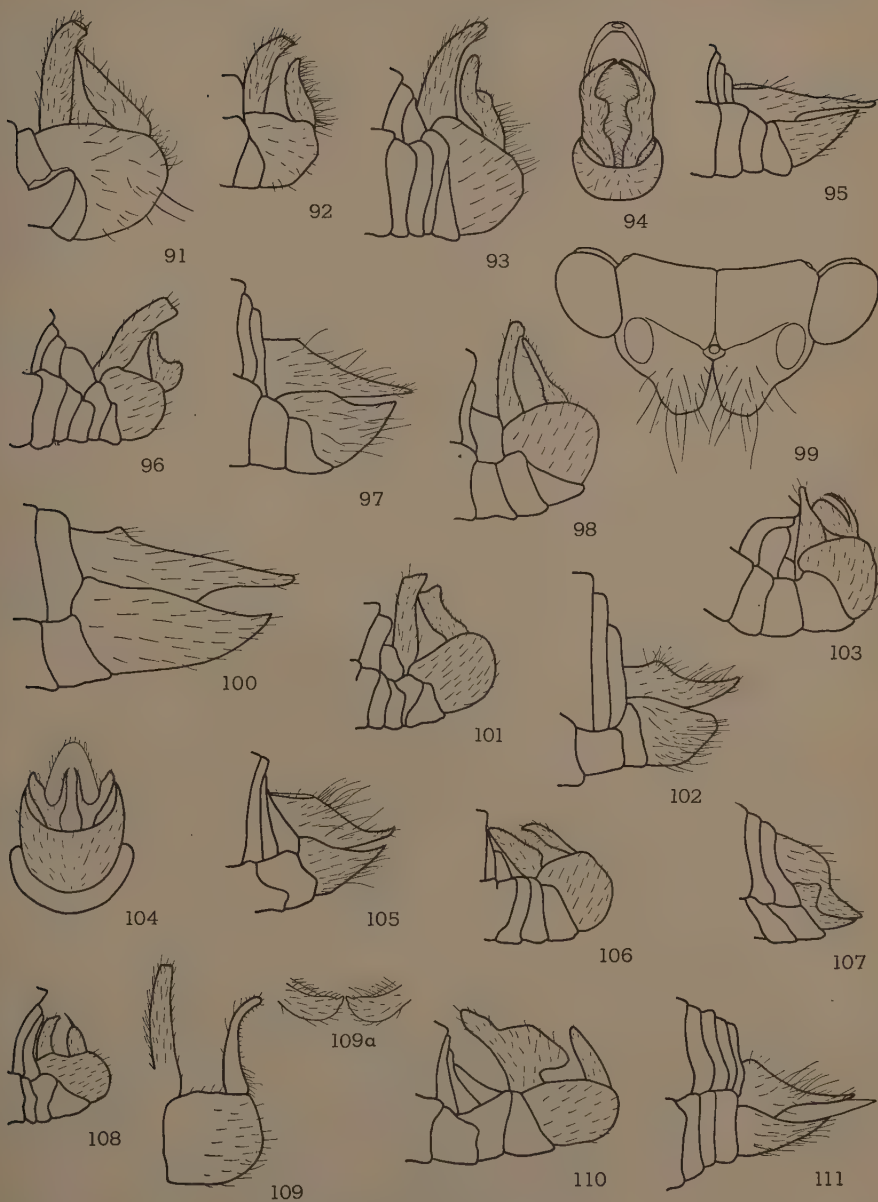
## PLATE VI

- FIG. 69. *Psylla manisii*—male cauda.  
70. *Psylla manisii*—female cauda.  
71. *Psylla quadrilineata*—female cauda.  
72. *Psylla quadrilineata*—male cauda.  
73. *Psylla confusa*—male cauda.  
74. *Psylla confusa*—female cauda.  
75. *Psylla parallela*—male cauda.  
76. *Psylla minor*—male cauda.  
77. *Psylla minor*—female cauda.  
78. *Psylla usitata*—female cauda.  
79. *Psylla usitata*—male cauda.  
79a. *Psylla usitata*—tip of forceps.  
80. *Psylla latiforceps*—female cauda.  
81. *Psylla latiforceps*—male cauda.  
82. *Psylla uncata*—male cauda.  
83. *Psylla uncata*—female cauda.  
84. *Psylla propria*—female cauda.  
85. *Psylla propria*—male cauda.  
86. *Arytaina spartiophila*—female cauda.  
87. *Arytaina amorphae*—male cauda.  
88. *Arytaina amorphae*—female cauda.  
89. *Arytaina pallida*—male cauda.  
90. *Arytaina pallida*—female cauda.



## PLATE VII

- FIG. 91. *Psylla americana*—male cauda.  
92. *Psylla americana curta*—male cauda.  
93. *Psylla sinuata*—male cauda, lateral aspect (Crawf.).  
94. *Psylla sinuata*—male cauda, caudal aspect (Crawf.).  
95. *Psylla fibulata*—female cauda (Crawf.).  
96. *Psylla fibulata*—male cauda (Crawf.).  
97. *Psylla annulata*—female cauda (Crawf.).  
98. *Psylla annulata*—male cauda (Crawf.).  
99. *Arytaina genistae*—head.  
100. *Arytaina genistae*—female cauda (Crawf.).  
101. *Arytaina genistae*—male cauda (Crawf.).  
102. *Arytaina fuscipennis*—female cauda (Crawf.).  
103. *Arytaina fuscipennis*—male cauda, lateral aspect (Crawf.).  
104. *Arytaina fuscipennis*—male cauda, caudal aspect (Crawf.).  
105. *Arytaina robusta*—female cauda (Crawf.).  
106. *Arytaina robusta*—male cauda (Crawf.).  
107. *Arytaina pubescens*—female cauda (Crawf.).  
108. *Arytaina pubescens*—male cauda (Crawf.).  
109. *Arytaina spartiophila*—male cauda (Sulc.).  
109a. *Arytaina spartiophila*—tip of forceps (Sulc.).  
110. *Arytaina assimilis*—male cauda (Crawf.).  
111. *Arytaina ceanothi*—female cauda (Crawf.).



## PLATE VIII

- FIG. 112. *Arytaina ceanothi*—male cauda (Crawf.).  
113. *Arytaina minuta*—female cauda (Crawf.).  
114. *Arytaina minuta*—male cauda (Crawf.).  
115. *Psyllopsiis fraxinicola*—female cauda (Crawf.).  
116. *Psyllopsiis fraxinicola*—head.  
117. *Psyllopsiis fraxinicola*—male cauda (Löw).  
117a. *Psyllopsiis fraxinicola*—forceps enlarged (Löw).  
118. *Psyllopsiis fraxini*—male cauda (Löw).  
119. *Psyllopsiis discrepans*—male cauda (Löw).  
120. *Euphalerus nidifex*—head (Crawf.).  
121. *Euphalerus nidifex*—female cauda.  
122. *Euphalerus nidifex*—male cauda.  
123. *Euphalerus vermiculosus*—head (Crawf.).  
124. *Euphalerus vermiculosus*—female cauda.  
125. *Euphalerus vermiculosus*—male cauda.  
126. *Euphalerus rugipennis*—male cauda.  
127. *Euphalerus rugipennis*—female cauda.  
128. *Euphyllura olivina*—female cauda.  
129. *Euphyllura olivina*—head.  
130. *Euphyllura olivina*—male cauda.



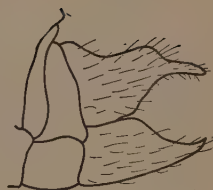
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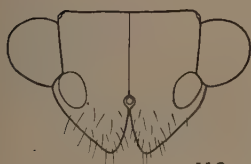
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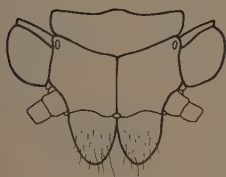
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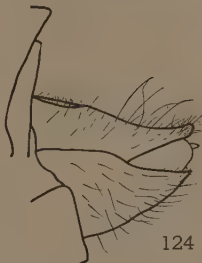
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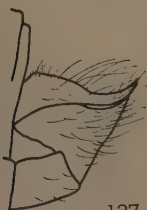
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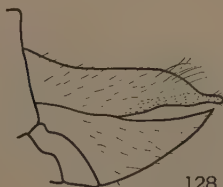
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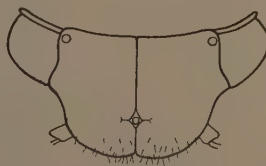
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## PLATE IX

- FIG. 131. *Euphyllura arctostaphyli*—head (Crawf.).  
132. *Euphyllura arctostaphyli*—female cauda.  
133. *Euphyllura arctostaphyli*—male cauda.  
134. *Euphyllura niveipennis*—female cauda.  
135. *Tetragonocephala flava*—head (Crawf. mod.).  
136. *Tetragonocephala flava*—forewing (Crawf.).  
137. *Pachypsylla venusta*—head (Crawf.).  
138. *Pachypsylla venusta*—female cauda.  
139. *Pachypsylla venusta*—forewing (Crawf.).  
140. *Pachypsylla venusta*—male cauda.



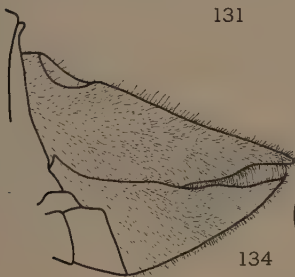
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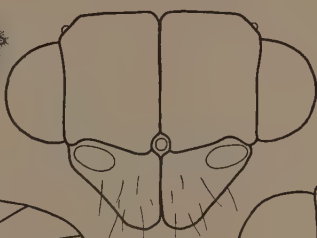
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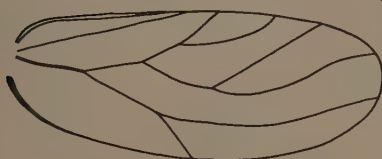
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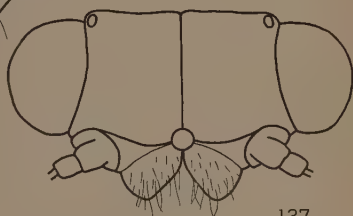
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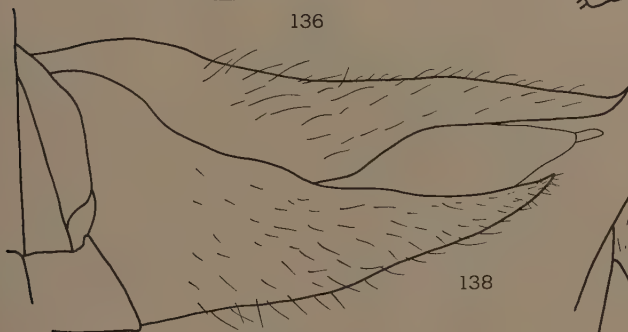
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## PLATE X

- FIG. 141. *Arytaina insolita*—male cauda.  
142. *Arytaina insolita*—female cauda.  
143. *Euphalerus jugovenosus*—female cauda.  
144. *Euphalerus jugovenosus*—male cauda.  
145. *Euphalerus adustus*—female cauda.  
146. *Euphalerus adustus*—male cauda.  
147. *Euphalerus tantillus*—female cauda.  
148. *Euphalerus tantillus*—male cauda.  
149. *Euphyllura separata*—male cauda.  
150. *Euphyllura separata*—female cauda.  
151. *Tetragonocephala flava*—male cauda.  
152. *Tetragonocephala flava*—female cauda.  
153. *Trioza pulla*—female cauda.  
154. *Trioza pulla*—male cauda.  
155. *Trioza singularis*—male cauda.  
155a. *Trioza singularis*—caudal aspect of forceps.  
156. *Trioza stygma*—male cauda.  
157. *Trioza stygma*—female cauda.  
158. *Trioza shepherdiae*—male cauda.  
159. *Trioza shepherdiae*—female cauda.  
160. *Trioza occidentalis*—female cauda.  
161. *Trioza incerta*—female cauda.  
162. *Trioza incerta*—male cauda.



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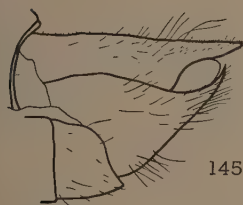
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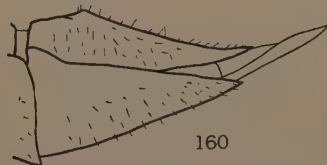
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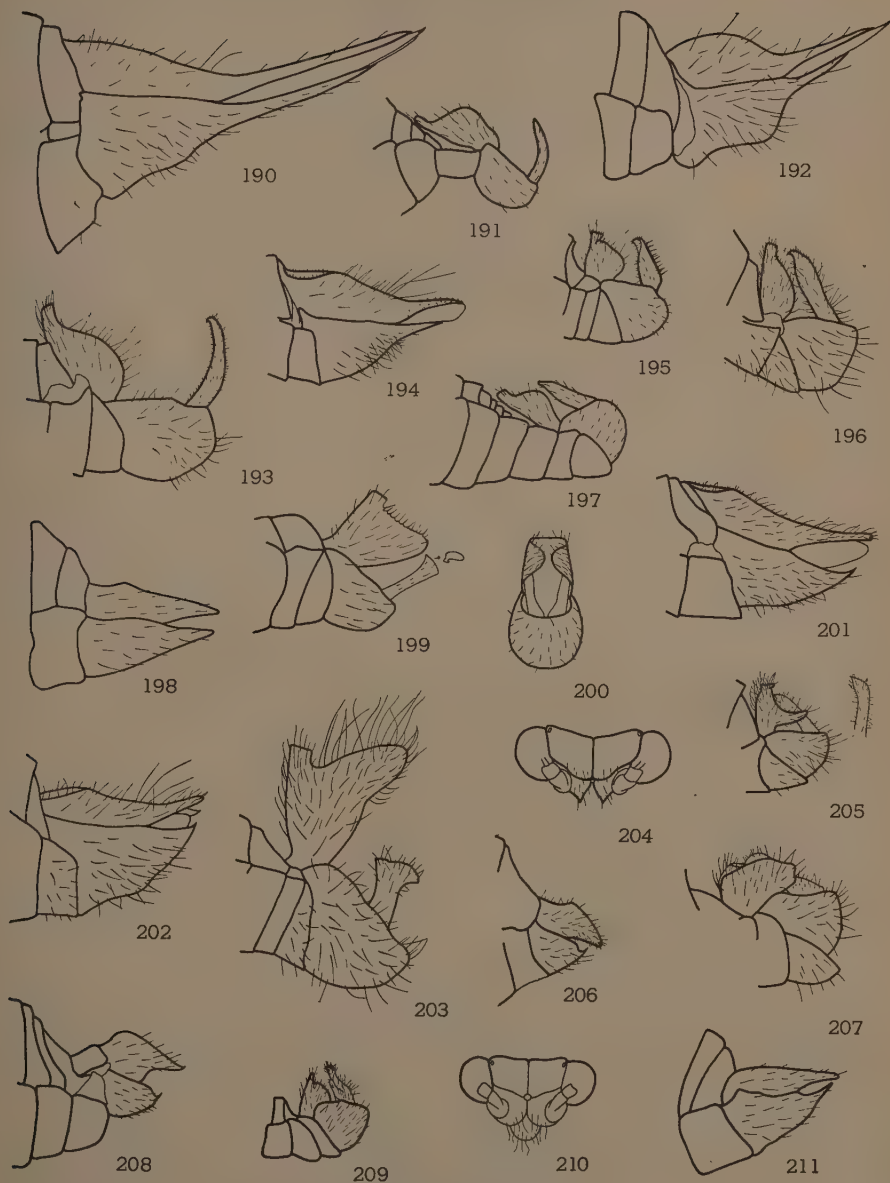
- FIG. 163. *Trioza urticae*—head.  
164. *Trioza urticae*—male cauda.  
165. *Trioza urticae*—female cauda.  
166. *Trioza viridis*—male cauda (Crawf. mod.).  
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171. *Trioza alacris*—male cauda (Essig).  
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175a. *Trioza rubicola*—caudal aspect of forceps.  
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178. *Trioza minuta*—male cauda (Crawf.).  
179. *Trioza minuta*—female cauda.  
180. *Trioza varians*—female cauda.  
181. *Trioza varians*—male cauda.  
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183. *Trioza lobata*—male cauda.  
184. *Trioza tripunctata*—female cauda (Peterson).  
185. *Trioza tripunctata*—male cauda (Peterson).  
186. *Trioza bakeri*—female cauda.  
187. *Trioza bakeri*—male cauda.  
188. *Trioza diospyri*—female cauda (Crawf.).  
189. *Trioza diospyri*—male cauda.





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- FIG. 190. *Trioza proximata*—female cauda.  
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192. *Trioza collaris*—female cauda (Crawf. mod.).  
193. *Trioza collaris*—male cauda.  
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195. *Trioza mexicana minor*—male cauda.  
196. *Trioza quadripunctata*—male cauda.  
197. *Trioza albifrons*—male cauda (Crawf.).  
198. *Trioza albifrons*—female cauda (Crawf.).  
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206. *Paratrioza cockerelli*—female cauda.  
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210. *Kuwayama medicaginis*—head (Crawf.).  
211. *Kuwayama medicaginis*—female cauda (Crawf.).



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- FIG. 212. *Trioza rubra*—female cauda.  
213. *Trioza rubra*—male cauda.  
213a. *Trioza rubra*—caudal aspect of forceps.  
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233. *Metatrioza pubescens*—male cauda.  
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235. *Levidea lineata*—male cauda.



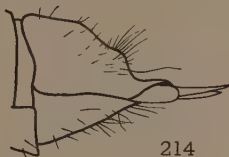
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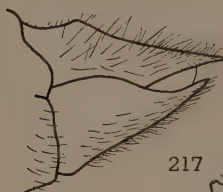
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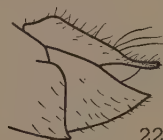
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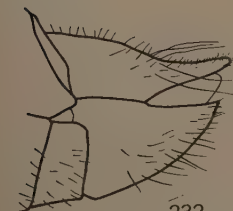
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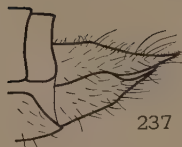
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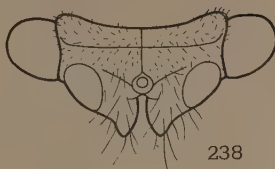
- FIG. 236. *Neotrioza pyrifolii*—head (Crawf.).  
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240. *Leuronota maculata*—female cauda (Crawf.).  
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245. *Hemitrioza sonchi*—forewing (Crawf. mod.).  
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253. *Trioza lobata*—forewing (Crawf.).  
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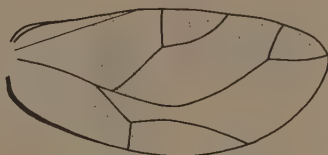
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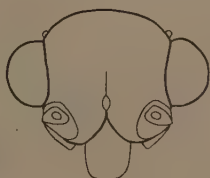
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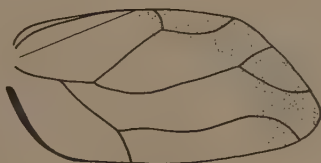
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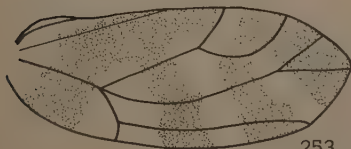
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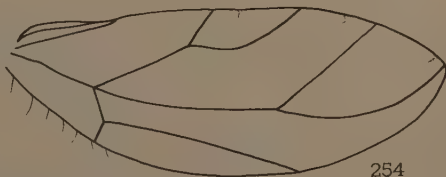
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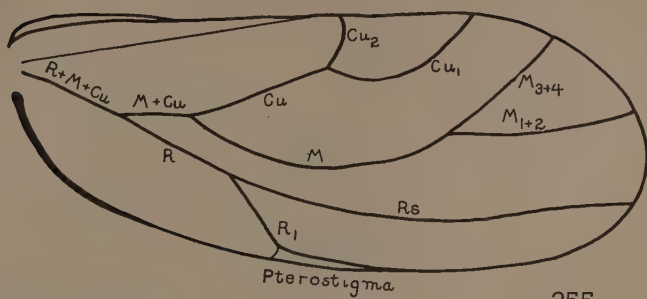


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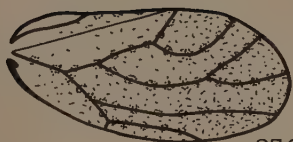


## PLATE XV

- FIG. 255. *Psylla alni*—forewing (Crawf.).  
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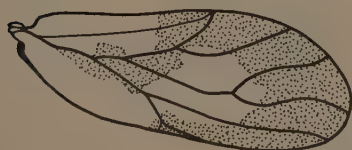
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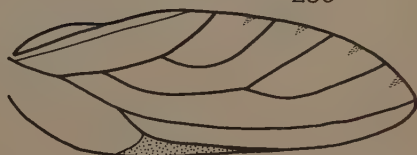
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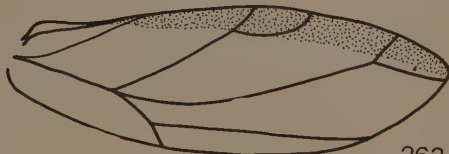
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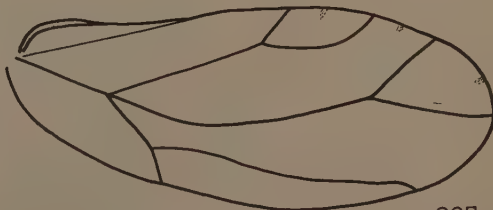
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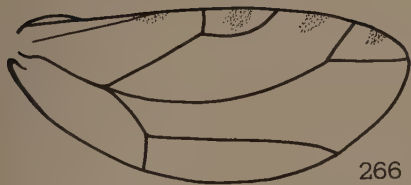
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- FIG. 266. *Trioza quadripunctata*—forewing (Crawf.).  
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273. *Paratrioza arbolensis*—forewing (Crawf.).  
274. *Neotriozella pyrifolii*—forewing (Crawf.).  
275. *Leuronota maculata*—forewing (Crawf.).



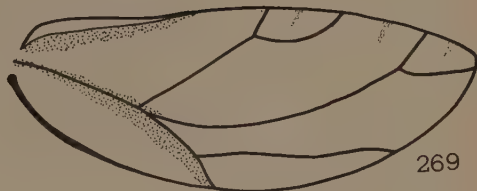
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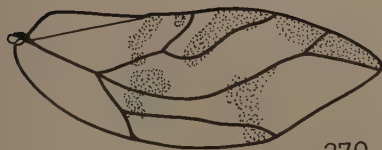
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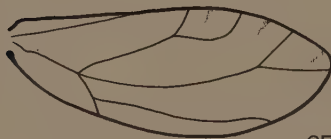
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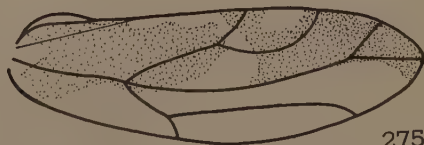
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## PLATE XVII

- FIG. 276. *Psylla phoradendri*—forewing.  
277. *Psylla nana*—forewing.  
278. *Psylla insignita*—forewing.  
279. *Psylla omani*—forewing.  
280. *Psylla hirsuta*—forewing.  
281. *Psylla media*—forewing.  
282. *Psylla alaskensis*—forewing.  
283. *Psylla bulbosa*—forewing.  
284. *Psylla manisi*—forewing.  
285. *Psylla confusa*—forewing.  
286. *Psylla usitata*—forewing.  
287. *Psylla latiforceps*—forewing.  
288. *Psylla uncata*—forewing.  
289. *Arytaina robusta sinuata*—forewing.



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## PLATE XVIII

- FIG. 290. *Arytaina spartiophila*—forewing.  
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292. *Arytaina insolita*—forewing.  
293. *Euphalerus jugovenosus*—forewing.  
294. *Euphalerus adustus*—forewing.  
295. *Euphalerus tantillus*—forewing.  
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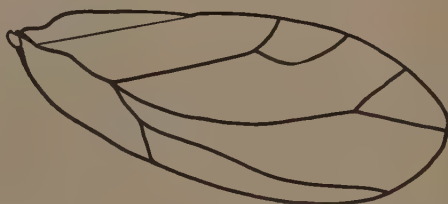
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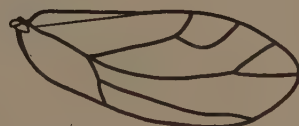
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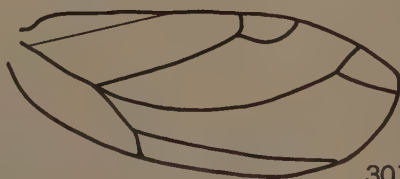
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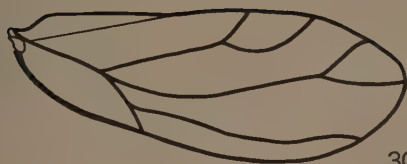
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- FIG. 302. *Trioza incerta*—forewing.  
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311. *Neotrizozella hirsuta*—forewing.  
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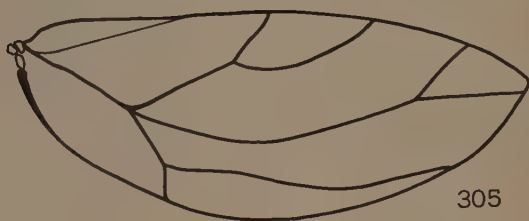
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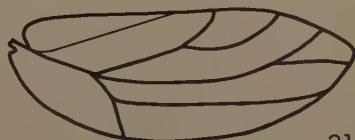
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